# DESIGN OF DATA ACQUISITION SYSTEM FOR ARTILLERY UNIT

*A Thesis Submitted in Partial Fulfillment of the Requirements for the Award of the Degree of*

***Master of Technology***

***in***

***Electronics & Instrumentation Engineering***

***by***


**Bibhuti Bhusan Pradhan**

**Roll No.210EC3315**

**Department of Electronics & Communication Engineering**

**NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA**

राष्ट्रीय प्रौद्योगिकी संस्थान, राउरकेला

**ODISHA, INDIA**


**2012**

# DESIGN OF DATA ACQUISITION SYSTEM FOR ARTILLERY UNIT

*A Thesis Submitted in Partial Fulfillment of the Requirements for the Award of the Degree of*

***Master of Technology***

***in***

***Electronics & Instrumentation Engineering***

***by***

Bibhuti Bhusan Pradhan
Roll No.210EC3315

Under the Guidance of

**Prof. Samit Ari**

**Prof. S.K. Patra**

**Department of Electronics & Communication Engineering**
**NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA**
राष्ट्रीय प्रौद्योगिकी संस्थान, राउरकेला
**ODISHA, INDIA**
**2012**

**Department of Electronics & Communication Engineering**

**National Institute of Technology, Rourkela**

# CERTIFICATE

This is to certify that the thesis entitled "**DESIGN OF DATA ACQUISITION SYSTEM FOR ARTILLERY UNIT"** by **Mr. BIBHUTI BHUSAN PRADHAN** submitted to the National Institute of Technology, Rourkela for the award of Master of Technology in Electronics and Communication Engineering, is a record of bonafide research work carried out by him in the Department of **Electronics and Communication Engineering** with specialization in **"Electronics and Instrumentation Engineering"** under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Dr. S.K.Patra
(Professor)

Dr. Samit Ari
(Asst. Professor)

Dept. of Electronics and Comm. Engineering
National Institute of Technology
Rourkela-769008

Place:

Date:

*Dedicated To my Parents*

# ACKNOWLEDGEMENT

First of all, I would like to express my deep sense of respect and gratitude towards my advisor and guide **Prof. Samit Ari** and **Prof. S.K. Patra** who has been the guiding force behind this work. I am greatly indebted to him for his constant encouragement, invaluable advice and for propelling me further in every aspect of my academic life. His presence and optimism have provided an invaluable influence on my career and outlook for the future. I consider it my good fortune to have got an opportunity to work with such a wonderful person.

I am very much thankful to our Head of the Department, **Prof. S. Meher**, for providing us with best facilities in the department and his timely suggestions. I am very much thankful to all my teachers **Prof. K. K. Mahapatra, Prof. T. K. Dan, Prof. U.C. Pati, Prof. S. K. Das** and **Prof. Poonam Singh** for providing me their valuable suggestions during my thesis work and for providing a solid background for my studies. They have been great sources of inspiration to me and I thank them from the bottom of my heart.

I also extend my thanks to all faculty members and staff of the Department of Electronics and Communication Engineering, National Institute of Technology, Rourkela who have encouraged me throughout the course of Master's Degree.

I would like to thank all my friends and especially my classmates for all the thoughtful and mind stimulating discussions we had, which prompted us to think beyond the obvious. I have enjoyed their companionship so much during my stay at NIT, Rourkela.

I am especially indebted to my parents for their love, sacrifice, and support. They are my first teachers after I came to this world and have set great examples for me about how to live, study, and work

Bibhuti Bhusan Pradhan

***Bibhuti Bhusan Pradhan***
Roll No: 210EC3315
Dept. of ECE

Date: 04/06/2012
Place: NIT Rourkela

# Contents

# Abstract

Data acquisition involves gathering signals that measure real world physical conditions from measurement sources and then modify it into different format for storage purpose. Typically a Data acquisition system converts physical signals which are analog in nature into digital form which is to be manipulated by a computer. In this work a multi channel data acquisition system is developed to acquire the data from Artillery unit in real time environment. More importance is given on the accuracy of the data captured and speed of operation of the developed data acquisition system.

Micro controller based hardware system is developed to generate prototype signals similar to the signal generated by the artillery unit. This is required to simulate firing pulses of the artillery unit in the laboratory to test the data acquisition system off line before implementing it in the real time environment.

The driver software is programmed to implement sixteen channel data acquisition system. The front end is designed in a simplified manner from the user point of view where several buttons with different nomenclature are placed for the corresponding operation of data. The capability of storage of data, retrieving the stored data in a graphical format for back analysis and instant calculation of different timing parameters during the data acquisition process made the overall system into a powerful and efficient tool. In addition to that another feature is implemented in this system where, the quest for a particular segment of stored data can be done instantly without putting any effort and necessary information can be obtained from that segment.

Further analysis of stored data is done where presence of error in the signal is detected. The data gets corrupted by noise during the process of firing which makes it difficult to detect the presence of error in the signal. Hence at the outset, the signal enhancement method is implemented to the data followed by which, the error detection method is applied to find out the presence of error.

# LIST OF FIGURES

# LIST OF TABLES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| DAQ | Data Acquisition |
| DAS | Data Acquisition System |
| PC | Personal Computer |
| PPI | Programmable Peripheral Interface |
| I/O | Input Output |
| CPU | Central Processing Unit |
| ADC | Analog to Digital Converter |
| DAC | Digital to Analog Converter |
| A/D | Analog to Digital |
| S/H | Sample and Hold |
| MUX | Multiplexer |
| PCI | Peripheral Component Interface |
| USB | Universal Serial Bus |
| DMA | Direct Memory Access |
| NI | National Instruments |
| VI | Virtual Instrument |
| LVM | LABVIEW Measurement |
| FFT | Fast Fourier Transform |
| WT | Wavelet Transform |
| DWT | Discrete Wavelet Transform |
| STFT | Short Time Fourier Transform |
| PSD | Power Spectral Density |

# *CHAPTER 1*

## ***INTRODUCTION***

*Introduction*

*Literature review*

*Motivation and objective of the Thesis*

*Organisation of the Thesis*

## 1.1 INTRODUCTION

Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound for storage, analysis and processing of data. Rapid advancement in Personal Computer (PC) hardware and software technologies have resulted in easy and efficient adoption of PCs in various precise measurement and complex control applications. A PC-based arrangement thus provides a flexible and highly cost effective alternative to these traditional data acquisition methods. Furthermore, systems can be easily configured to cope with the changing requirements of the user. So a PC-based data acquisition system uses a combination of modular hardware and flexible software to transform in standard laptop or desktop computer into a user- defined measurement or control system.

In this project work a multichannel PC based data acquisition system is developed which will be suitably used to gather data from artillery unit in real time environment. There are sixteen different sensors are located at different places of artillery unit which corresponds to each stage of operation of the system. The different signals which are generated from the sensor provide valuable information about the process of operation of artillery unit. A suitable data acquisition system is designed with a user friendly front end to acquire those sixteen signals into a Personal computer. The signals required to operate the artillery unit are basically square wave signals bearing different frequencies as well as amplitude. The range of frequencies of those signals varies from 2Hz to 5 Hz. In this real time environment, there happens a tremendous vibration of mechanical equipments during firing. Therefore while designing a data acquisition system in this scenario; the primary concern was about the robustness as well as the accuracy of output of data acquisition system.

A USB based data acquisition card, “NI 6218” is employed to acquire the data where sixteen channels are configured as analog input. The data acquisition card is housed inside a box which is covered by transparent material. All the terminal pins of data acquisition card are replaced with banana female port to avoid any unfastened connection. To reduce the possibility of interference among channels, coaxial cables terminating with banana pins are used. Some essential parameter related to data acquisition process like sampling frequency, voltage range of the signal etc. need to be adjusted before the commencement of the data acquisition process. LABVIEW which itself is the trademark of National Instrument is used as application software to drive the data acquisition card. LABVIEW is designed to display all the sixteen signals graphically in an individual manner.

Besides estimating some of the essential timing information in the acquired signal, a more detail analysis is performed to detect any presence of error. In this work, wavelet based signal enhancement technique is proposed to remove the noise from acquired signal. Doubechies wavelet with order 1 is used to decompose the signal up to four levels. Empirically chosen thresholds are applied in each detail coefficient and the de noised signal is reconstructed using the approximation coefficient and threshold detail coefficients. To detect the error Doubechies wavelet with order 4 is applied to decompose the enhanced signal up to eight levels. Each detail coefficient represents the distortion if original signal is erroneous. The proposed method is tested by means of signal to noise ratio, average power and spectrogram analysis. Experimental result shows that the performance of the proposed method is consistently well at different SNR both off line testing and online testing, and also be able to detect the error properly.

## 1.2 Literature Review

The literature on applications and fundamentals regarding design of Data acquisition system is very extensive. Now a days in any type of computer aided manufacturing project work and laboratory tests, accuracy and consistency of instrumentation and data acquisition techniques causes major impacts on results and outcomes. Hence a comprehensive knowledge regarding Data acquisition system is essential to obtain signal on manufacturing, testing, measurement, and protection areas. At the outset Literature review has been done on the 8051 microcontroller basics to generate essential timing signals [1-2], followed by concepts on data acquisition systems also done. “PC based instrumentation” concepts and practice by N. Mathivanan is a right choice to start for Data acquisition fundamentals through PC [3]. In addition to that, Kevin James describes about PC interfacing in data acquisition system [4]. In the book “PC based instrumentation and control” Mike Tooley has provided sufficient information to be able to select the necessary hardware and software to implement a wide range of practical PC-based instrumentation and control systems [5]. Various knowledge can be acquired from several measurement books regarding different instruments and basic measuring units like OPAMP, instrumentation amplifier etc. [6-8]. Some different design aspects regarding DAS [9] and LABVIEW has been followed form various materials [10-12]. Some materials regarding different approach to DAS has been followed where in most of the cases LABVIEW is implemented as application software [13-15]. Some books regarding design of LABVIEW has been followed [16], [17]. An essential guide entitled “LABVIEW for Everyone 2nd Edition” by Travis (2002) covers also fundamentals to advanced levels of

LABVIEW Environment, and interfacing the computer to the real world [18]. The material for introduction to PC based data acquisition by Heinz Rongen is an excellent material which gives the essentials of data acquisition system in a very precise manner. Data Acquisition and Signal Conditioning Course Manual (National Instrument 2003) provides a deep knowledge about the DAQ hardware where the structure and configuration of a data acquisition card is covered in a greater detail [20]. A basic concept about LABVIEW is best described in the material “LABVIEW analysis and concept” (National Instrument 2004) where the analysis is given in relation to the DAQ hardware [21]. From the data acquisition manuals published by National Instruments the knowledge behind DAQ hardware configuration, designing concepts by LABVIEW, several essential real time constraints, factors affecting DAQ system, some important parameters regarding DAQ etc. can be covered in detail [20-23]. Towards the end of this project, a detail study has been done on the Wavelet Transformation for error detection of the acquired signal. Some papers regarding signal enhancement and error detection has been reviewed and different methods were followed [24-26]. J. Cusido, L. Romeral, J.A. Ortega, A. Garcia and J.R. Riba, in their paper has implemented various fault detection method on the Wavelet based decomposed signal [24]. S.G. Mallat, “A Wavelet Tour of Signal Processing,” is a handy guide to review about Wavelet transformation [27].

## 1.3 Motivation and Objective

Proper signal acquisition is required to detect and analyze the operation of each section of artillery unit. Therefore several sensors are located at different places to acquire the signal. In this context, a plotter is used to plot the sensor output in a piece of paper during the course of operation of artillery unit. Several drawbacks exist in this process where the primary one includes all the merits of soft copy over the hard copy. In addition to that the data plotted need to be evaluated for extracting relevant timing information which is a time consuming process and it also includes some human error like parallax error and calculation error. Since the data cannot be saved permanently, it will be impossible for future analysis regarding operation. The above reason has motivated me to search for an alternative to overcome the discussed problem.

So the primary objective of this thesis is to:

- Generate sixteen voltage signals in parallel from the microcontroller based hardware system.
- Design a sixteen channel based data acquisition system to acquire voltage signals from the artillery unit and save the signal for future reference.
- To implement the DAS with the help of LABVIEW as application software and design a user friendly front end for easy operation.
- To detect the presence of error in the acquired signal for diagnosis purpose.

## 1.4 Organisation of Thesis

This thesis is divided into five different chapters including introduction, the details of which are outlined below in a precise manner.

**Chapter1**: This chapter covers the introduction, motivation & objective of the project. It also includes the literature review on data acquisition system using LABVIEW as well as thesis organisation.

**Chapter2**: Basic concepts of 8051 microcontroller as well as 8255 programmable peripheral interface are discussed in this chapter. Internal architecture and pin configuration of 8051 microcontroller is explained. I/O ports of 8255 PPI are discussed in detail through which sixteen signals are to be generated in parallel.

**Chapter3**: In this chapter the concept of Data acquisition system is explained. Different types of DAS, data acquisition accessories, software requirement in DAS, configuration of DAQ hardware, signal conditioning requirement etc are described in detail. Apart from that factors affecting performance of DAQ and some design constraints regarding hardware as well as software are explained.

**Chapter4**: Error detection in the acquired signal is done in this chapter. Basic concepts behind Wavelet transform, STFT, and average power are described for quick review. The process of signal enhancement in the acquired signal followed by which error detection in the enhanced signal is implemented using wavelet transforms method.

**Chapter5**: Finally in this chapter the conclusion and future works are outlined.

# *CHAPTER 2*

---

## ***GENERATION OF PROTOTYPE SIGNAL***

*Introduction*

*8051 Microcontroller internal architecture*

*8255 Programmable peripheral interface (PPI)*

*Methodology*

*Results and discussion*

## 2.1 Introduction

Micro controller based hardware is developed for generating prototype signals similar to the signal generated by the Artillery Unit. This is required to simulate firing pulses in the laboratory to test the proposed Data acquisition system off-line. This hardware set-up is also useful to test the Data acquisition system since the acquired data from transducers may be affected by spurious signals in real time environment. Hence the need of generation of prototype signals is due to:

- Sixteen parallel signals cannot be fed to the data acquisition card externally through function generator or any other mode.
- We can create a real time environment virtually in the laboratory and able to find out some problems regarding faulty connections, improper ground etc.
- The prototype signals corrupted with errors cannot be generated from the function generator externally.

The prototype signals similar to the signals required by the artillery unit are generated with the help of 8051 Microcontroller based hardware along with 8255 Programmable peripheral interface (PPI). In this chapter some basic features and essential pin configuration of 8051 Microcontroller which is used in laboratory is explained here. In addition to that a brief discussion of 8255 Programmable peripheral interface which is embedded in 8051 microcontroller is given.

## 2.2 8051 Microcontroller description

The microcontroller is a true computer on a chip. Microcontroller is general purpose device, which is able to execute a series of pre-programmed operations and interact with other hardware devices. The 8051 is an 8-bit microcontroller which signifies that most of the available operations in the 8051 microcontroller are limited within 8 bits [1]. It has own internal architecture, register set, instruction set etc. All the operations within the microcontroller are performed at high speed. Figure 2.1 shows the pin configuration of the 8051, where the function of each pin is written next to it. Here the pins that have dual functions (P0, P2 and P3), can still be used normally as an input/output pin. Unless program uses their dual functions, all the 32 I/O pins of the microcontroller are configured as input/output pins.

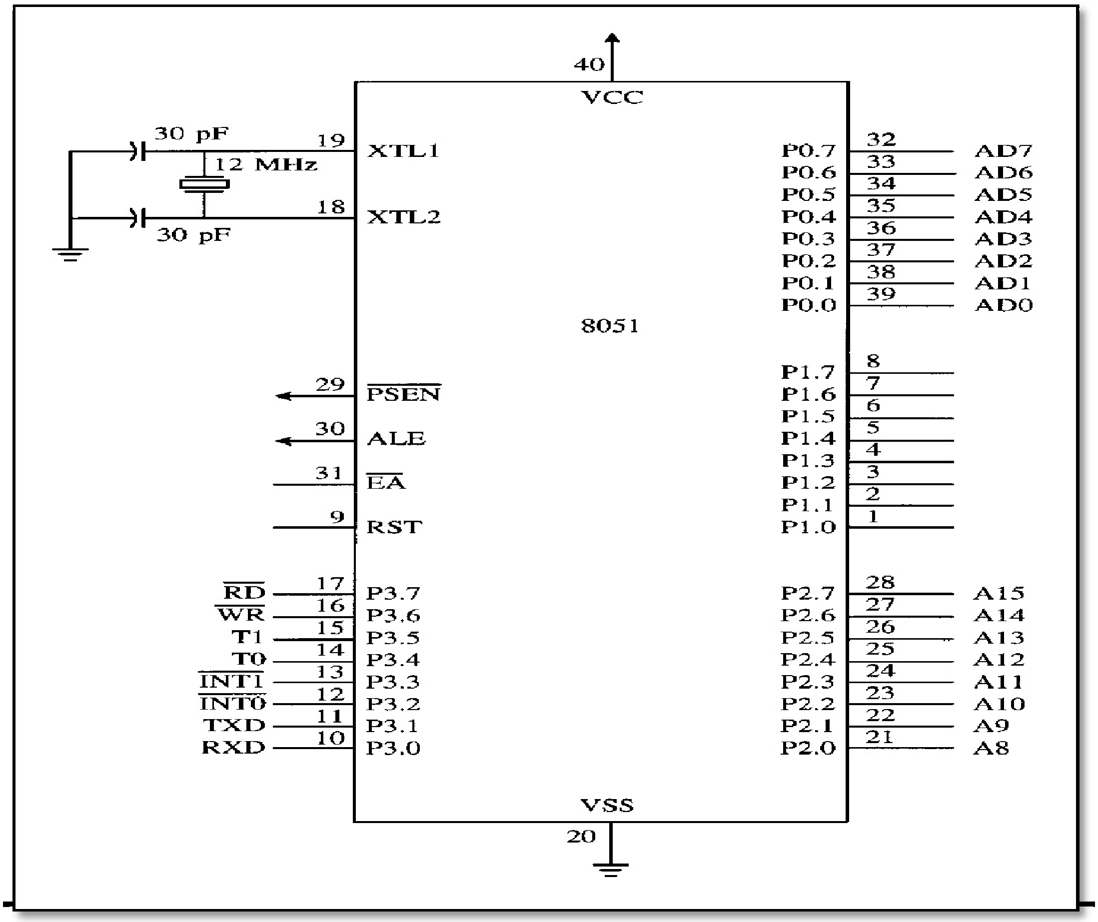



Figure 2.1: Microcontroller based hardware pin diagram

## 2.3 8051 Microcontroller Internal Architecture

The 8051 is the name of a big family of microcontrollers. It has 4 different ports, each one having 8 Input/output lines providing a total of 32 I/O lines. Those ports can be used for output DATA and for interfacing with other peripheral devices, or to read the state of a sensor, or a switch. Figure 2.2 represents the detail internal architecture of 8051 microcontroller. Some of the ports of the 8051 family have dual function which signifies that they can be used for two dissimilar functions. The primary function of the pin will be to perform input/output operations. In addition to that the pin will be used to apply some particular operation of the microcontroller like external pulse count, interruption of the execution of the ongoing program in accordance with external events external events, executing serial data transfer like connecting the chip to a personal computer or laptop for data transfer etc. Each port of the 8051 microcontroller has a total of eight pins, and from software point of view this eight bit unit is assigned as ‘register’, where, each bit of the register being connected to different I/O pin.

8051 contains two variety of memory as RAM and EEPROM where, RAM is used to store variable during program execution, where as EEPROM memory is used to store the program

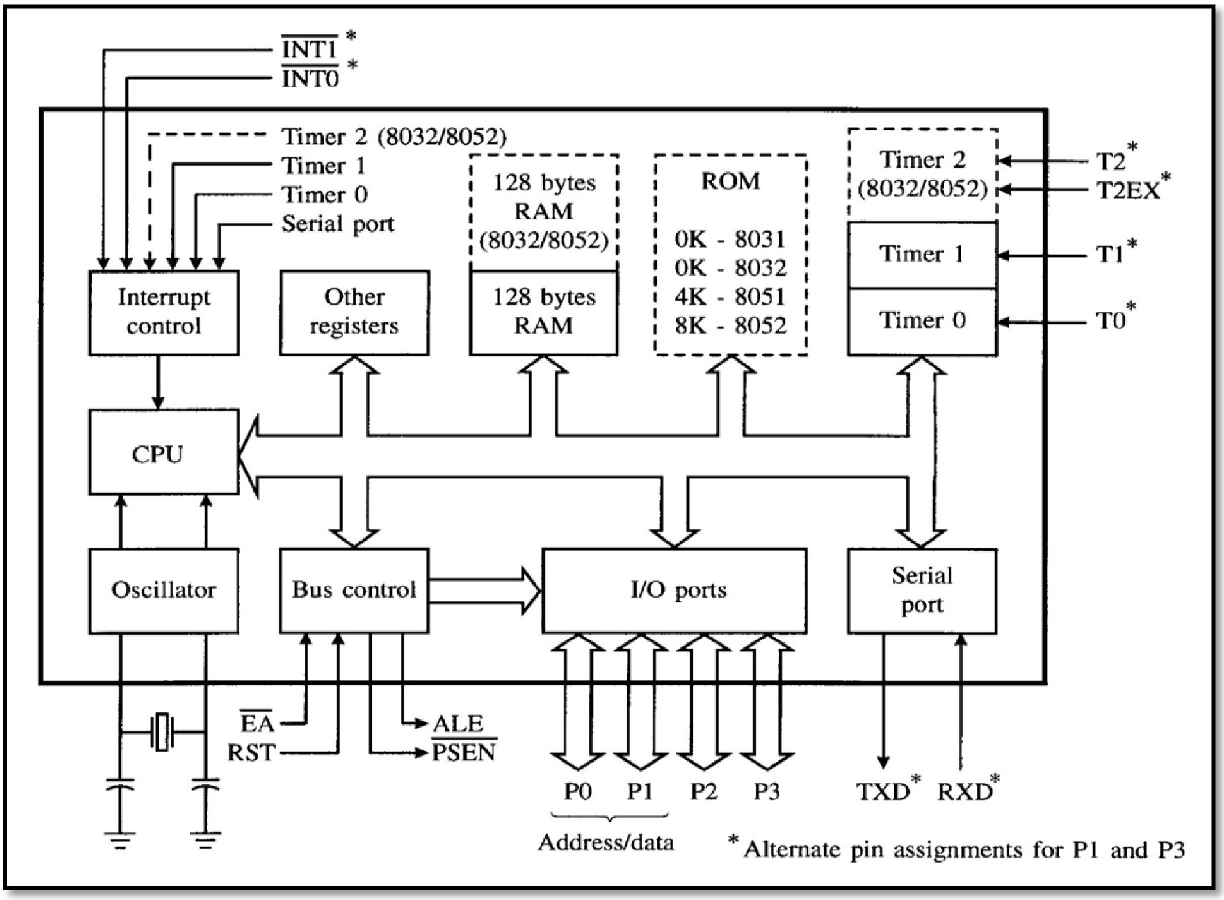



Figure 2.2: 8051 Microcontroller Internal architecture

itself. Due to this reason EEPROM is referred as the 'program memory'. The CPU which stands for Central Processing Unit is the heart of the microcontrollers. The essential job of CPU is to Read the program from the FLASH memory and execute it in accordance with the different peripherals. Description of each block of 8051 microcontroller is given in section 2.2.1.

### 2.3.1 Pin configuration of 8051 microcontroller

Each port of P0, P1, P2, and P3 uses 8 pins making them 8 bit ports. All the ports upon RESET are configured as inputs, ready to be used as input ports.

PORT P0 (pin 32 to 39): PORT P0 can be used as a general purpose 8 bit port when no external memory is present, but if external memory access is required then PORT P0 acts as a multiplexed address. Data bus can be used to access external memory in conjunction with PORT P2. P0 acts as AD0-AD7.

PORT P1 (Pin 1 to 8): The port P1 is a general purpose input/output port which can be used for a variety of interfacing tasks. Upon RESET, port P1 is configured as an input port.

PORT P2 (pin 21 to 28): It can be used as input/output port. Upon RESET port P2 is configured as an input port. For accessing external memory PORT P2 will act as an address bus in conjunction with PORT P0 to access external memory. PORT P2 acts as AD8-AD15.

PORT P3 (Pin 10 to 17): Although PORT P3 can be used as a normal input port upon reset, but generally it is used for other specific purposes. P3.0 & P3.1 are used as serial communications, P3.2 & P3.3 are utilized for receiving external interrupts, P3.4 & P3.5 are used for timer 0 and 1 respectively whereas Read & write signals are received by P3.6 & P3.7 of 8051 microcontroller.

### 2.3.2 Oscillator Circuit

An external oscillator circuit is required for 8051 microcontroller for generating clock cycles. The operating frequency of this oscillator circuit is around 12MHz. Therefore, each machine cycle in the 8051 consists of 12 clock cycles. Since oscillator circuit generates clock pulses with fixed frequency during operation, all internal operations which depend on clock cycle are synchronized [2].

### 2.3.3 Timer and Counter

The 8051 microcontroller has two timers: timer 0 and timer 1. They can be used either as timer or as event counter. Each 16 bit timer is accessed as two separate registers of low byte and high byte which is referred as TL AND TH respectively. Both timers 0 and 1 uses the same register called TMOD register to set the various timer operation modes. In this project mode 2 operation is used which has auto-reloading capability where the TH and TL value need not be supplied by the programmer in each iteration.

### 2.3.4 Data and Programme Memory

The 8051 consists of three very general types of memory.

- On-Chip Memory refers to any memory (Code, RAM, or other) that physically exists on the microcontroller itself. Code memory is the memory that holds the operating machine code which is used as an input by the user. This memory is limited to 64K and comes in many shapes and sizes: Code memory may be found on-chip, either burned into the microcontroller as ROM or EPROM [28].

- External Code Memory is code (or program) memory that resides off-chip. This is often in the form of an external EPROM.
- External RAM is RAM memory that resides off-chip. This is often in the form of standard static RAM or flash RAM. External RAM is any random access memory which is found off-chip. Since the memory is off-chip, it is not as flexible in terms of accessing, and is also slower [28].

There are 128 bytes of RAM in the 8051. These amounts of RAM memory inside the microcontroller are assigned addresses 00 to 7F. They can be directly accessed like memory location. These 128 bytes are divided into 3 different groups as Register bank 0-3, bit addressable RAM and scratch pad RAM, where register bank 1 uses the same RAM space as the stack.

8051 family of microcontroller has 64K bytes of on-chip ROM. So the first location of on-chip ROM inside the 8051 microcontroller starts with address 0000H and ends with FFFFH.

## 2.4 8255 Programmable Peripheral Interface (PPI)

The 8255 is widely used as a programmable parallel I/O device. It is flexible, versatile, and economical.

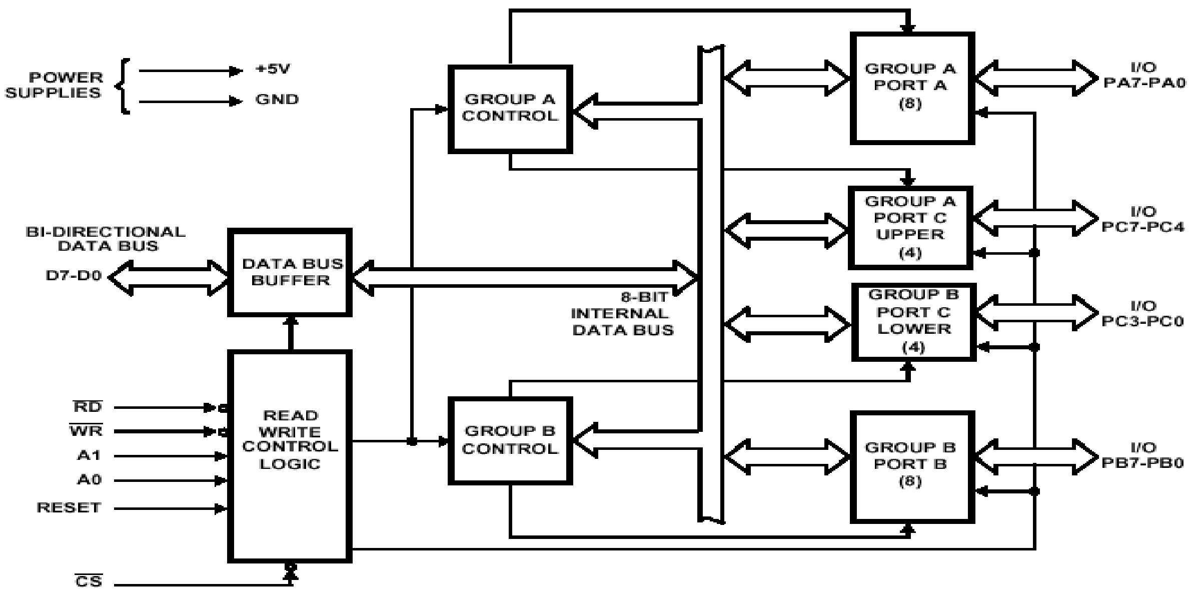



Figure 2.3: Internal architecture of 8255 (PPI)

**Functional Block of 8255:**

The 8255 comprises 24 input/output pins. They may be treated as three 8-bit ports. Port A as well as port B is used as 8-bit input/output ports. Whereas Port C is used as an 8-bit input/output port or can be used as two 4-bit input/output ports. Port C can generate handshake signals for port A and port B.

The three ports are further grouped as follows:

- Group A consisting upper part of port C along with port A.
- Group B consisting of lower part of port C along with port B.

8 data lines, D0 to D7 are accessible with an 8-bit data buffer to read/write data into the ports or control register according to the status of the RD and WR, which are active low signals for read and write operations respectively. The address lines A1 and A0 can be used to select any one of the port or the control register as given in Table 2.1.

Table 2.1: Port selection in 8255 (PPI)

| A1 | A0 | SELECTION |
|---|---|---|
| 0 | 0 | PORT A |
| 0 | 1 | PORT B |
| 1 | 0 | PORT C |
| 1 | 1 | CONTROL REGISTER |

The ports of 8255 can be programmed to be operated in any of the four different modes. The Mode 0 is simple input/output mode. In this mode any of the three ports can be programmed as input or output port. In mode 1 port A and B can be used as input or output ports with handshaking capabilities where handshaking signals are provided by the bits of port C. In port 2 port A can be used as bidirectional I/O port with handshaking capabilities with port C. Port B can be used as either in simple I/O mode or handshaking mode 1. In BSR mode only the individual bits of port C can be programmed.

## 2.5 Methodology

Microcontroller based generated test signals along with error signals are acquired to the computer with the help of the designed data acquisition system. Along with that, two analog signals (sine waves generated from function generator) were also acquired for laboratory test.

The microcontroller based hardware setup is built along with a Digital Storage Oscilloscope (DSO) to generate fourteen signals in parallel. The signals are displayed with the help of a sixteen channel mixed signal oscilloscope. With the help of a bread board and external power supply, the necessary triggering signal is also generated. The complete setup for prototype signal generation process is shown in Figure 2.4.

Fourteen test signals are generated in parallel which bears frequency of either 2Hz or 1Hz. The parallel signals are generated by monitoring the transitions of all the signals in a single period and then repeating the same process for subsequent periods. The delay subroutine is called when a transition occurs for any one of the fourteen signals for a certain amount of time and during this period; the state of that particular signal is changed at the output keeping the other signals unchanged. This condition persists until the arrival of a new transition for any one of the signals.


Figure 2.4: Microcontroller setup for signal generation

1.085 micro seconds delay occurs for a single machine cycle of 8051 microcontroller. To get a fixed amount of delay the TCON register is to be set accordingly inside the delay subroutine. In a single period, the delay subroutine is called repeatedly with different time range until a delay of 1000 ms occurs in total.

## 2.6 Results and discussion

In this project 8051 microcontroller is used which is programmed such that only Port P1 can be used as general purpose input/output port. So to generate 14 signals in parallel, 8255 programmable peripheral interface is used. Out of 3 ports(port A, Port B & Port C), Port A and Port B are used as output ports to generate required signals which are prototype signals as produced by the transducer's output that are placed in artillery unit for receiving the temporal information of sub-system during firing.

The TMOD register is loaded with a value #20 to use the Timer1 in mode 2 operations. The control register of 8255 is loaded with a value #80 to use the Port A and Port B as I/O port. In this microcontroller the location of port address for Control register is at FFOF. Whereas the address for Port A, B and C is located at FF0C, FF0D and FF0E respectively.

One of the pin of the 8051 is configured as input port which provides necessary triggering signal to start the process. The circuit diagram of this process is shown in Figure 2.5.

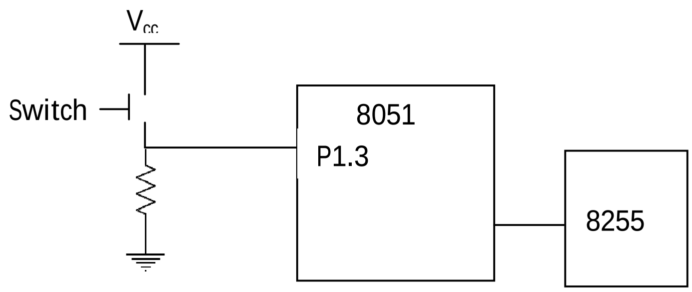
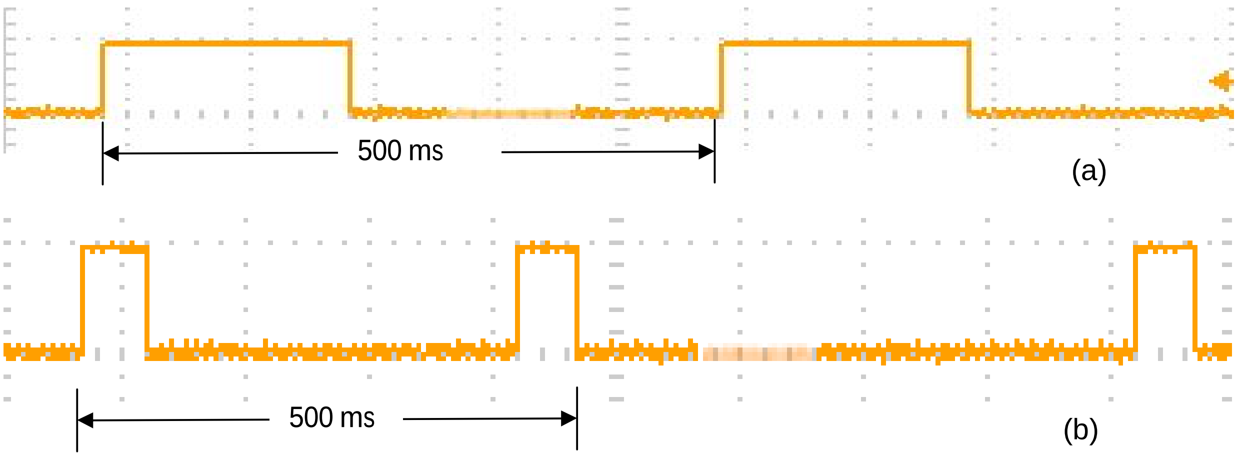
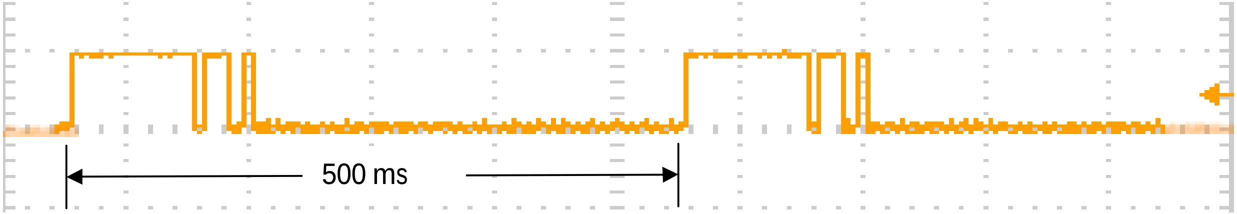



Figure 2.5: Circuit diagram for generation of triggering pulse

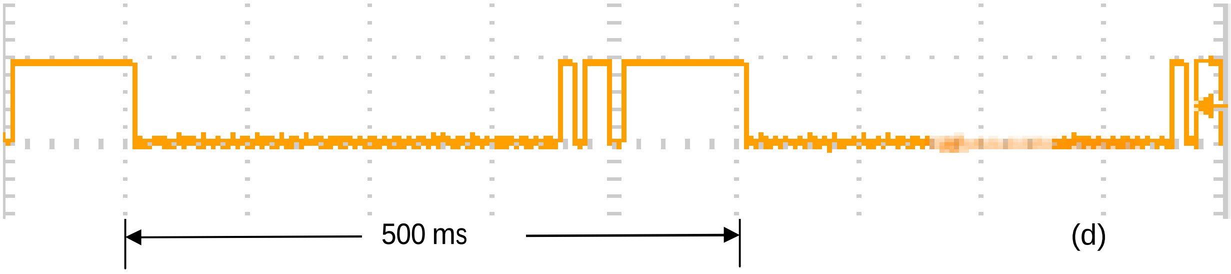
The triggering signal is generated with the help of a bread board and a 12V power supply. The signals which are displayed in oscilloscope are shown in Figure 2.6 which shows the prototype signals that provide necessary timing information for each section of the artillery unit.

(TIME PERIOD: 500ms)

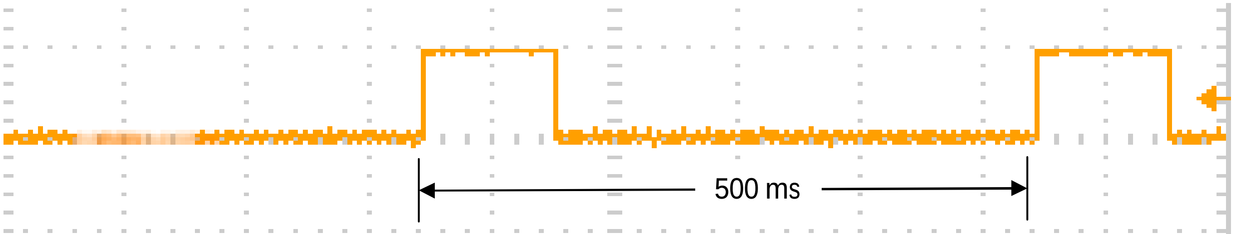





(c)

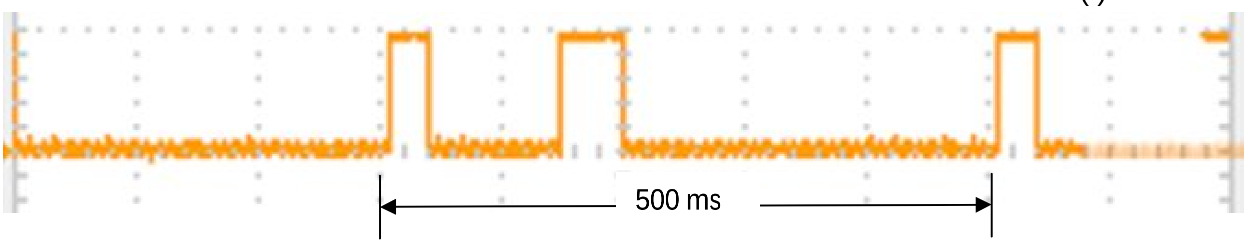



(d)

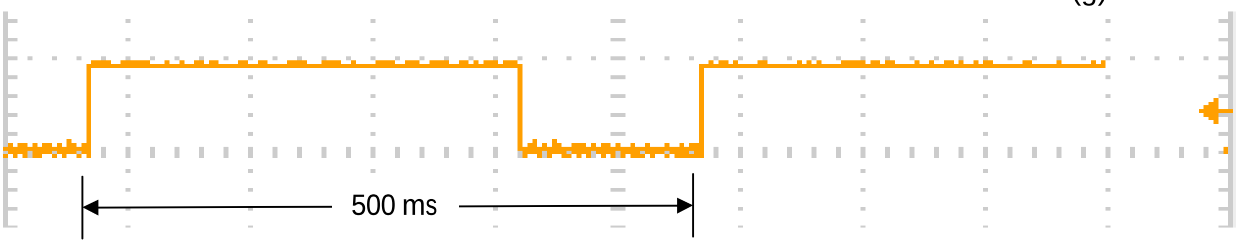



(e)


(f)




(g)




(h)

(TIME PERIOD: 1000 ms)

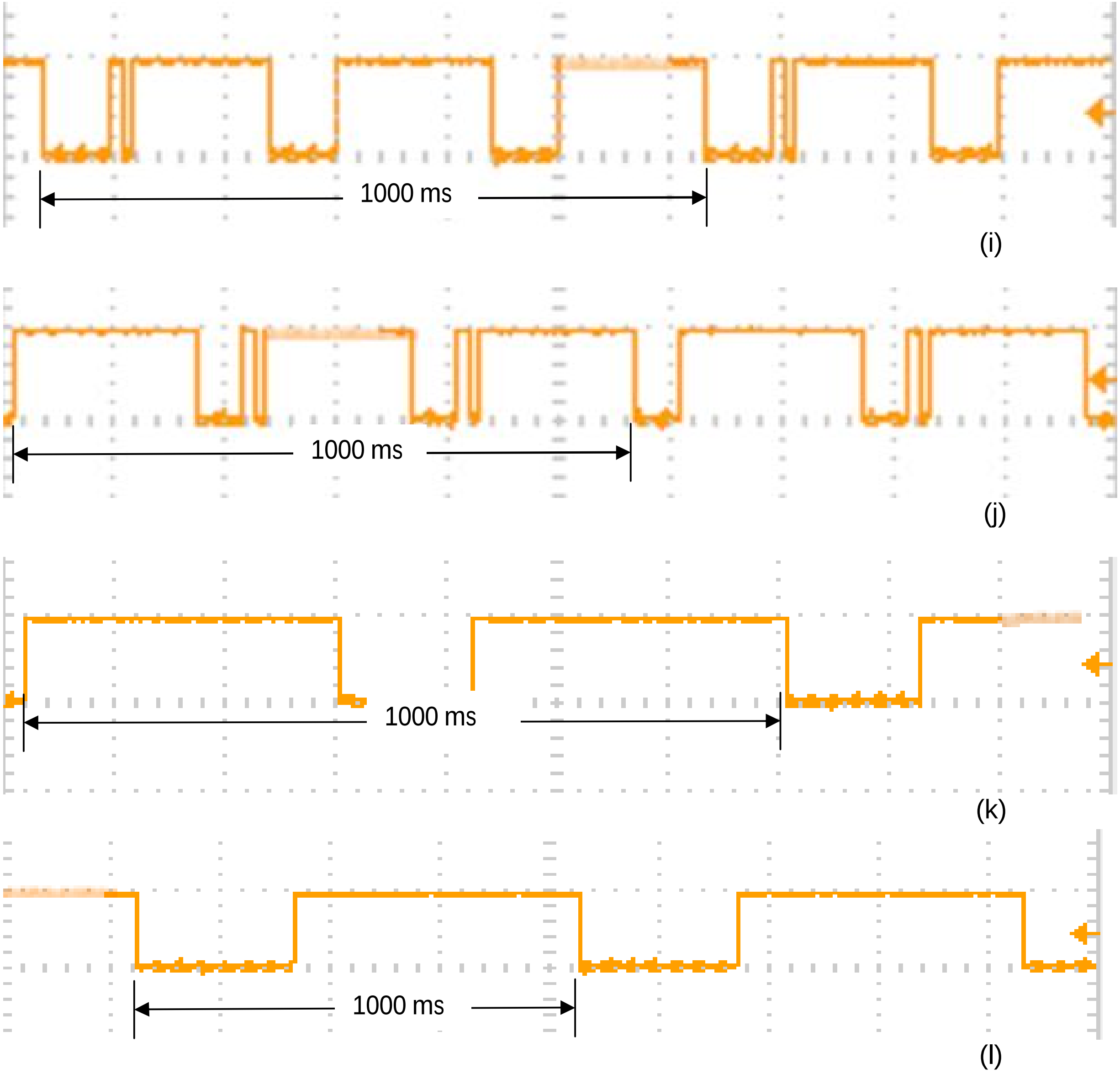



Figure 2.6: Generated prototype signals with the help of microcontroller based hardware

The generated test signals shown above are to be acquired by a data acquisition system into the PC recurrently to figure out the errors occurred in the data acquisition system. Along with that two more analog signals need to be acquired simultaneously.

# ***CHAPTER 3***

## ***DATA ACQUISITION SYSTEM***

*Introduction*
*DAQ Accessory*
*DAQ hardware description*
*Factors affecting performance of DAQ*
*DAQ software using LABVIEW*
*Methodology*
*Results and discussion*

## 3.1 Introduction

A data acquisition system, or DAQ, may be defined as those components participating in the process of transforming physical phenomena into electrical signals which are then measured and converted into digital format for collection, processing, and storage by a computer. So in more elaborately we can say that: A data acquisition system consists of many components that are integrated to:

- Sense physical variables
- Condition the electrical signal to make it readable by an A/D board
- Convert the signal into a digital format acceptable by a computer
- Process, analyze, store, and display the acquired data with the help of software

Before going deep into data acquisition system we can broadly classify data acquisition system as

- Single channel data acquisition system
- Multi channel data acquisition system

### 3.1.1 Single channel data acquisition system

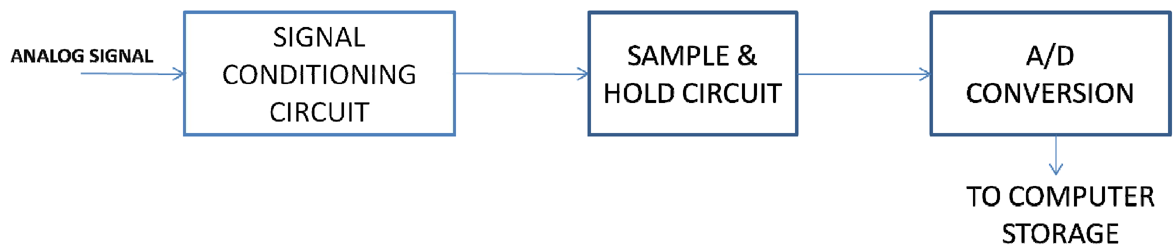



Figure 3.1: Block diagram of single channel data acquisition system

In single channel data acquisition system we can able to sense only one type of physical parameter at a time. As shown in the Figure 3.1 the basic elements of the single channel DAQ are a signal conditioning circuit, a sample and hold circuit and most importantly an A/D converter circuit [3]. But when our requirement will be more we don't want to confine within a single channel single channel data acquisition system. We want to acquire multiple number of physical parameter in a single time; alternatively we need a multi channel single channel data acquisition system.

### 3.1.2 Multi channel data acquisition system

In multi channel data acquisition system, we can able to acquire multiple parameters or different version of data for the same parameter in a single time by which we can increase our efficiency as well as throughput to a much higher level. The block diagram of the multi channel data acquisition system is shown in Figure 3.2.

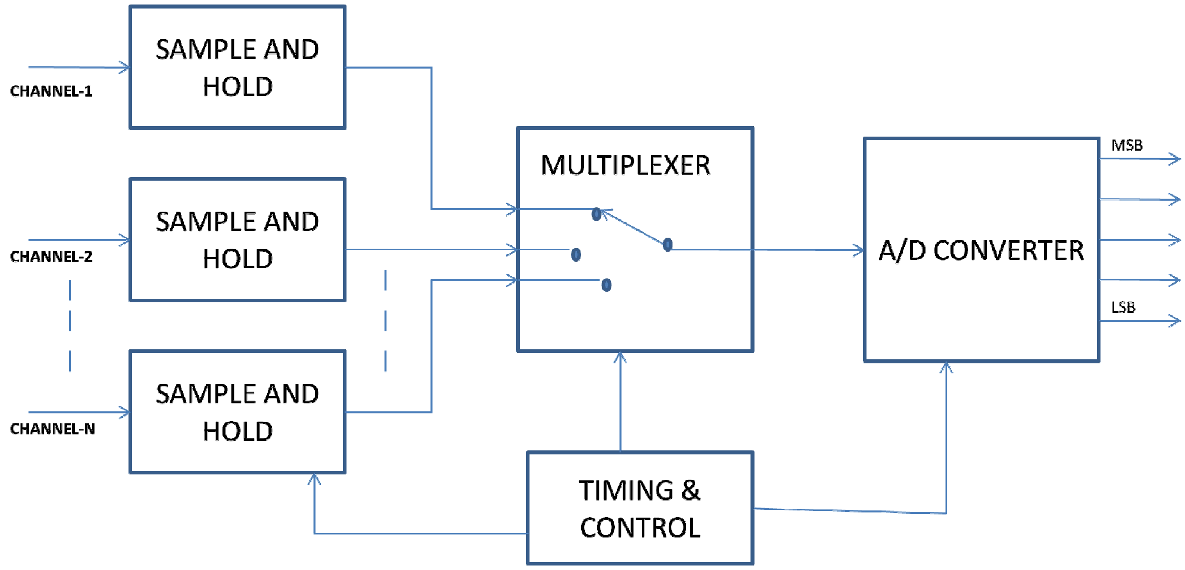



Figure 3.2: Block diagram of multi channel data acquisition system

Here we need multiple numbers of sample and hold circuits as well as A/D converter circuits. But the S/H circuit is simple in construction and cheaper one as compared to A/D circuit which serve here as the primary component having more complicated circuit and more cost. So from cost point of view it is not suitable to implement multiple numbers of A/D converter circuits. Therefore here we have used a single A/D converter with a multiplexer, although keeping an A/D converter for each channel is more accurate than a single A/D circuit. Sample and hold circuit is having easy and simple architecture resulting into a cheap configuration. Hence we will not hesitate to connect multiple numbers of samples and hold circuit in each channel.

## 3.2 Data acquisition accessories

So basically, the components of data acquisition system are:

• Sensors and Transducers

• Signal conditioning circuit

• DAQ hardware

• Driver and application software

The basics of DAQ hardware and software will be discussed in next section.

### 3.2.1 Sensor and transducer

Data acquisition begins with the physical phenomenon to be measured. This physical phenomenon may be the temperature of a room, the intensity of light source, the pressure inside a chamber, the force applied to an object, or many other things [27]. A good DAQ system can measure all of these different phenomena. A transducer is a device that converts a physical phenomenon into a measurable electrical signal, such as voltage or current [6]. The ability of a DAS to measure different phenomena depends on the transducers to convert the physical phenomena into signals measurable by the DAQ hardware. Transducers are synonymous with sensors in DAQ systems [7]. There are specific transducers for many different applications like measuring temperature, pressure, or fluid flow.

### 3.2.2 Signal conditioning requirement

Transducers generated signals are too difficult to measure directly with a data acquisition device. For instance, when dealing with high voltages, noisy environments, and extreme high and low signals, or simultaneous signal measurement, signal conditioning is essential for an efficient DAQ system. It will maximize the accuracy of the system which allows sensors to operate properly, and guarantees safety. Design of a signal conditioning circuit varies from application to application. [3] Basically, the job of the signal conditioning circuit is for,

- Amplification
- Attenuation
- Filtration
- Isolation

## 3.3 Data acquisition hardware

DAQ hardware acts as the interface between the laptop or computer and the outside world. It primarily functions as a device that digitizes incoming analog signals so that the PC can interpret them. Generally data acquisition system performs the following operations:

- Analog input
- Analog output
- Counter or timer
- Multifunction (combination of analog, digital and counter operations in a single device)

So the basic components of data acquisition hardware are:

### 3.3.1 Multiplexer

The multiplexer is a switch that connects only one channel from several input channels to the instrumentation amplifier at a time. When the data is acquired from multiple channels, the multiplexer rotates through the channels, connecting them one at a time to the amplifier. LABVIEW controls the order in which the multiplexer connects the incoming signals to the amplifier [19].

### 3.3.2 Sample and hold circuit

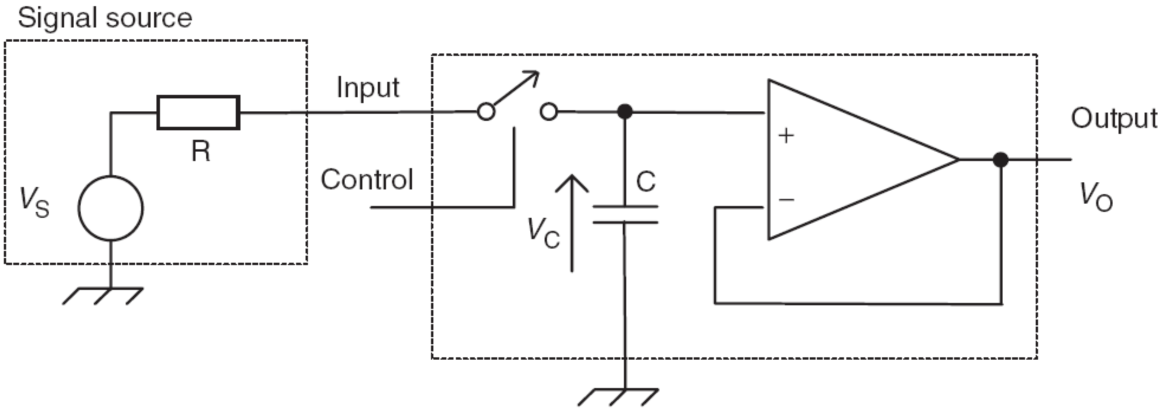



Figure 3.3: Sample and hold circuit

Many systems employ a sample-and-hold (S/H) circuit on the input to the ADC to freeze the signal while the ADC digitizes it [8]. This prevents errors due to changes in the signal during the digitization process. In some implementations, the multiplexer can be switched to the next channel in a sequence as soon as the signal has been grabbed by the S/H. This allows the digitization process to proceed in parallel with the settling time of the multiplexer and amplifier, thereby enhancing throughput. S/H circuits can also be used to capture transient signals.

### 3.3.3 Signal conditioning circuit

The operation of signal conditioning circuit is same as was explained earlier. Only difference in this module is that it is used inside the data acquisition hardware. In general, an Instrumentation amplifier is used as a signal conditioning circuit [8]. The purpose of the amplifier is to modify the signal such that it will fill the range of the ADC as much as possible [19].

### 3.3.4 A/D Converter

A/D Converter converts (ADC) an analog voltage into a digital number which can be sent to the computer for interpretation using the computer input output interface circuitry. The analog input circuitry combines with the analog to digital converter to acquire analog signal, hence the level, shape, or frequency of that signal can be measured [9].

There basically three types of ADC are there, such as-

1. Dual ramp (slow with very high accuracy, for precision measurements)
2. Flash converter (fast, lesser accuracy, for video or radar)
3. Successive approximation (medium speed and accuracy, for general-purpose industrial applications, commonly found in embedded systems)

### 3.3.5 D/A Converter

D/A Converter (DAC) perform the opposite task of an ADC. It accepts a digital number which was sent from the computer through the input output interface circuitry and converts it into an analog signal that is output through the input output connector [16]. A DAC is required for generating DC signals (level) [9], specific tones (frequencies), and waveforms (shapes).

### 3.3.6 Driver and application software

The Data acquisition (DAQ) software transforms the whole system into a single integrated module as a result we can have a control over the DAQ hardware. Without application software to control or drive the hardware, the data acquisition device will not work properly [10-12].

Driver software is the layer of software to easily communicate with the hardware. It forms the intermediate layer between the application software and the hardware. Driver software also prevents a programmer from having to do register-level [27] programming or complicated commands to access the hardware functions.

The application layer can be either a development environment in which a custom application can be built which meets specific criteria, or it can be a configuration-based program with preset functionality. Application software adds analysis and presentation capabilities to driver software.

## 3.4 PC Based data acquisition system

PC-based data acquisition uses a combination of modular hardware and flexible software to transform in standard laptop or desktop computer into a user- defined measurement or control system. The computer we use for the DAQ system can drastically affect the maximum speeds at which we can continuously acquire data. As computers continuously improve, the DAQ system can take advantage of the computer's enhanced capabilities, including improved real-time processing. PCI bus and USB port are standard equipment on most of today's desktop

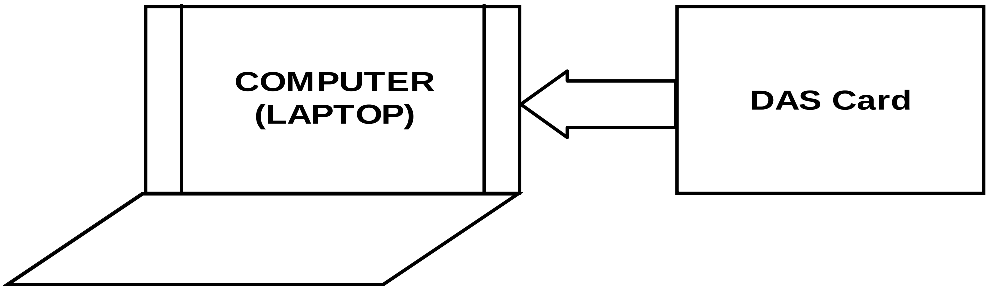



Figure 3.4: DAQ Card connected with a Laptop

Computers and yield up to 132 Mbytes/s theoretical data transfer capabilities.

For remote or distributed DAQ applications, we can place measurement nodes near sensors and signal sources and use standard networking technology, such as Ethernet, serial, or wireless. When choosing a DAQ device and bus architecture, we should keep in mind the data transfer methods supported by our chosen device and bus and the transfer rates.

The data transfer capabilities of computer can significantly affect the performance of DAQ system. Direct memory access (DMA) transfers, implemented on almost all of today's personal computers, increase the system throughput by using dedicated hardware to transfer data directly into system memory. PCI, ISA, and IEEE 1394 devices offer both DMA and interrupt-based transfer method whereas PCMCIA and USB devices use only interrupt-based transfer method. The chosen transfer method will affect the achievable throughput of your DAQ device.

## 3.5 Configuration of DAQ hardware

The data acquisition hardware is the heart of building a data acquisition process, because this is the system where the data is actually modified and prepared to be accepted by computer. Here we mean the data acquisition hardware as a DAQ board installed in a PC. Most DAQ devices have four standard elements which are to be used as: analog input, analog output, digital I/O, and counters.

### 3.5.1 Data acquisition hardware architecture

We can transfer the signal measured with the data acquisition device to the computer through several different bus structures. For example, a data acquisition device can be used which plugs into the PCI bus of a computer, a data acquisition device connected to the PCMCIA socket of a laptop, or a data acquisition device connected to the USB port of a laptop.

Depending on the speed of the motherboard of the computer, the maximum data transfers can occur between microprocessor and memory at 20 MHz to 40 MHz [19] .The Figure 3.5 shows the component of a DAQ device.

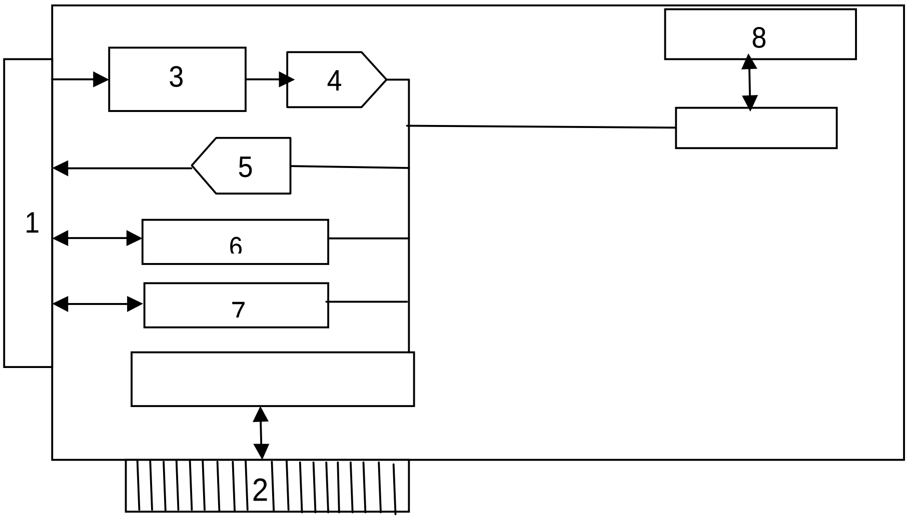



Figure 3.5: Basic components of a DAQ device

The role of each block is given below according to the number assigned to the block.

So the components which constitute a data acquisition system are:

1. I/O Connector
2. Computer I/O Interface Circuitry
3. Real-Time System Integration (RTSI) Bus
4. Analog input circuitry
5. ADC
6. DAC
7. Digital input output circuitry
8. Counter circuitry

A typical DAQ device has three interfaces for receiving and sending signals:

a. I/O connector
b. Computer I/O interface circuitry
c. Real-Time System Integration (RTSI) Bus

a. I/O Connector – This is the connector through which the signal enters or leaves the data acquisition device. One end of the cable will be connected to the I/O connector where as the other end will be connected to the terminal.
b. Computer I/O Interface Circuitry - The computer I/O interface circuitry transfers data between the data acquisition device and the laptop or computer. The Computer input output interface circuitry will differ depending on the bus protocol which is used. For example, the PCI bus has connection leads that plug into a PCI slot, where as the USB connection requires a cable.
c. RTSI Bus – This is the bus which shares and synchronizes data between multiple data acquisition devices in the same computer or laptop. For example, if it is required to perform analog input two devices at the same rate then a single clock signal can be shared over the RTSI bus so both devices use the same clock signal.

Generally the analog signal is received by ADC after sampling. This digitally converted data is received by the computer. So inside the computer the data is again converted back to its analog counterpart.

The functionality of some block and their importance are described below:

A. **Sampling** - The signal is acquired by an ADC using a process called sampling. Sampling an analog signal occurs at discrete time intervals [13]. The frequency at which the signal is sampled is known as the sampling frequency. The sampling frequency determines the ability of the analog to digital conversion process. A Higher sampling frequency results into better conversion of the analog signals. The minimum sampling rate required to reconstruct the signal should be at least twice the maximum frequency content of the analog signal which is called the Nyquist rate.
B. **ADC** - Once the sampling process is over, the analog signal is converted into a digital code and this method is called analog to digital conversion. Precision of the ADC conversion process is dependent upon the number of bits the ADC circuit uses. The resolution of the converted signal is a function of the number of bits the ADC uses to represent the digital signal. The higher the resolution, the higher the number of divisions the voltage range is broken into, [13] and therefore, the smaller the detectable voltage changes.
C. **Settling time** - On a typical board, the analog signals are first selected by a MUX, and then get sampled before it is converted by the ADC circuit. The sample & hold circuit used between the multiplexer and the ADC must be able to track the output of the

MUX, otherwise the ADC will convert the signal that is still in transition from the previous channel value to the current channel value [13]. Poor settling time is a key problem because it changes with sampling rate and the gain of the DAQ board.

## 3.6 Factors to be considered while designing a DAQ

There are many factors to be considered while designing a Data Acquisition System which is described as below.

a. Fixed or a mobile application-The configuration depends upon the type of application. For fixed supplication we can choose a PCI DAQ card, which cannot be moved in frequently. But for mobile application we should a USB based DAQ, which will be handy to use.
b. Type of input/output signal- if the input signal is a digital one we do not require a extra ADC circuit, unlike in the case of analog signal. The presence of an ADC circuit affects much in a DAQ system.
c. Frequency of input signal- according to the frequency of the input signal we need to specify the sampling frequency accordingly. If the input frequency is not known difficulties increases to some extent while choosing sampling frequency. We may apply hit and trail method in that case.
d. Needed Resolution, range, and gain- range, resolution and gain are important parameters to get a accurate data as discussed earlier.
e. Continuous or fixed operation-DAQ operation that do not have predetermined number of samples, or that runs for lengths of time that a single buffer of data is too large to practically to fir into memory may need to make a use of continuous acquisition. In continuous acquisition we use a circular buffer.
f. Compatibility between hardware and software- there must be available software which should be compatible to a particular hardware. Driver software is also necessary to operate.
g. Overall price of the system- the overall price of the system depends upon all the factors we have just discussed. More specifically it depends upon number of channel, analog or digital operation, and fixed or movable operation.

## 3.7 Factors affecting performance of data acquisition system

There are several factors which provide direct impact upon the performance of the Data acquisition system. The performance of the data acquisition system indicates the ideal behavior which varies according to the required application. So the objective of a data acquisition should be:

- It must acquire the necessary data at correct speed and time.
- Use of all data efficiently to inform about the state of plant or process.
- It must monitor the complete plant operation to maintain adequate safety.
- It must be able to collect, summarize and store the data for diagnosis of operation and storage purpose.
- It must be flexible and capable of being expanded for future requirement.

Different factors which affect the performance of DAS are described as below.

**A. Signal Conditioning Requirement**

Signal conditioning circuit improves the quality of the signals generated by transducers before they are converted into digital signals by the data acquisition hardware [19-22]. The signal conditioning can be implemented according to the requirements which are discussed as below.

- **Amplification-** Signal conditioning circuitry with amplification, which applies gain outside of the computer as well as near to the signal source, can increase the resolution and also effectively reduce the effects of noise. Boosting the signal range uses as much of the ADC input range as possible. If the signal range is very small (milivolt or microvolt) then amplifying these low-level signals directly on the DAQ board also amplifies any noise picked up from the lead wires or from within the computer or laptop. When the input signal is in microvolt range this noise can dominant over the signal itself which will lead to inaccurate data. The noise can be reduced by taking some precautions as:
    - ❖ Use of shielded cables or twisted pair of cables.
    - ❖ Minimize wire length to minimize noise the lead wires pick up.
    - ❖ Keep signal wires away from AC power cables and monitors.
- **Isolation**- Isolation is used to suppress the unwanted signal from safety point of view. When the data acquisition device input and the signal being acquired are each referenced to ground and the difficulty starts when there exist a potential difference in the two grounds. This difference can lead to problem what is known as a ground loop, which may cause inaccurate representation of the acquired signal. For larger difference damage can occur to the measurement system. Isolating signal conditioners

can break these ground loops and reject very high common-mode voltages. Isolators also provide an important safety function by protecting against high-voltage surges from sources like power lines, lightning, or high-voltage equipment.

- **Filtering-** The purpose of a filter is to remove unwanted signals from the signal which is to be measure. If the signals are not removed, they will erroneously appear as signals within the input bandwidth of the device. Filtering can be implemented in hardware as well as in software. Most noise is created by AC power like computer power supply or overhead lights where noise occurs at around 60 Hz. A low pass filter can be used with a cut-off frequency less than 60 Hz to remove noise.

## B. Resolution

The number of bits used to represent an analog signal determines the resolution of the analog to digital converter. Higher the resolution is on a data acquisition device, more will be the number of divisions into which a system can break down the analog to digital converter range and therefore, the smaller the detectable change.

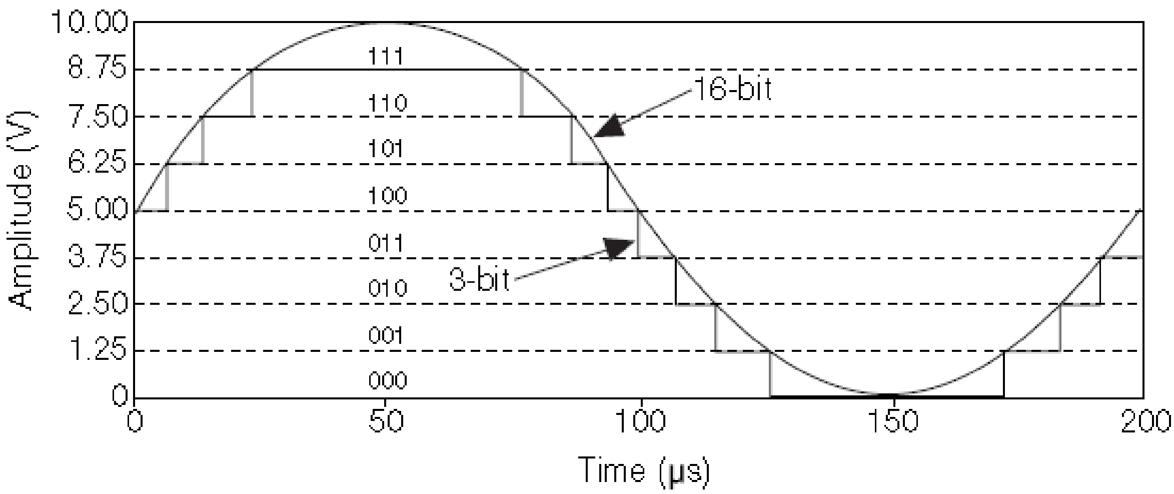



Figure 3.6: Effect of resolution over accuracy of the digitized signal

The Figure 3.6 shows a sine wave and its corresponding digital image as obtained by an ideal 3-bit analog to digital converter. A 3-bit converter divides the analog range into 8 divisions. Each division is represented by a binary code between 000 and 111. Clearly, the digital representation is not a good representation of the original analog signal because information has been lost in the conversion. By increasing the resolution to 16 bit, however, the number of codes from the ADC circuit increases from 8 to 65,536, and therefore an extremely accurate digital representation of the analog signal can be obtained.

**C. Range**

Range refers to the minimum and maximum analog signal levels that the ADC circuit can digitize. Many data acquisition devices feature selectable ranges (typically 0 to 10 V or –10 to 10 V), so the ADC range can be matched to that of the signal to get the best advantage of the available resolution to accurately measure the signal. For example, as shown in the Figure 3.7, the 3-bit ADC in left hand side of figure has eight digital divisions in the range which varies from 0 to 10 V, is a unipolar range. If the range which varies from –10 to 10 V (a bipolar range) is selected, as shown in right hand side of figure, the same analog to digital converter separates a 20 V range into eight divisions. The smallest voltage level that can be detected increases from 1.25 to 2.50 V, and the right hand side chart is a much less accurate representation of the signal.

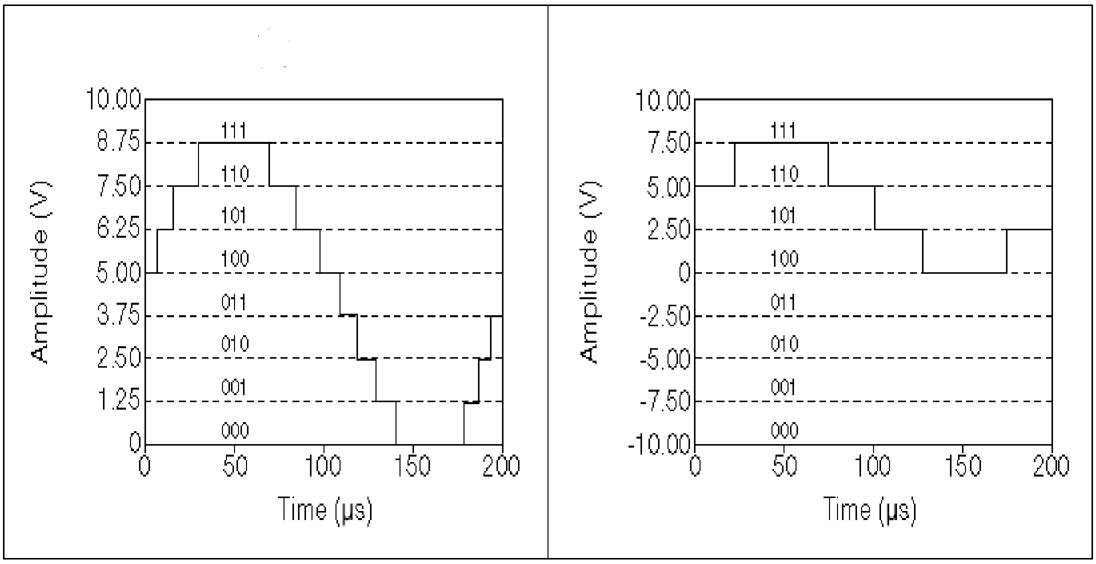



Figure 3.7: Effect of Range over accuracy of digitized signal

**D. Gain**

Gain of a signal may occur before the signal is converted to digital format to further improve the representation of the signal. By amplifying or attenuating a signal, the input range of an analog to digital converter and thus allows the analog to digital converter can be decreased effectively to use as many of the available digital divisions as possible to represent the signal. The following example illustrates the effects of applying amplification to the signal which fluctuates between 0 and 5 V using a 3-bit analog to digital converter and a range of 0 to 10 V. With no amplification, or gain = 1, the analog to digital converter uses only four of the eight divisions in the conversion. By amplifying the signal by twice before digitizing, the analog to digital converter uses all eight digital divisions, and the digital representation is much more accurate. Here, the device has an allowable input range of 0 to 5 V because a signal above 5 V when amplified by a factor of 2 supplies the input to the analog to digital converter greater than 10 V which is shown in the Figure 3.8.

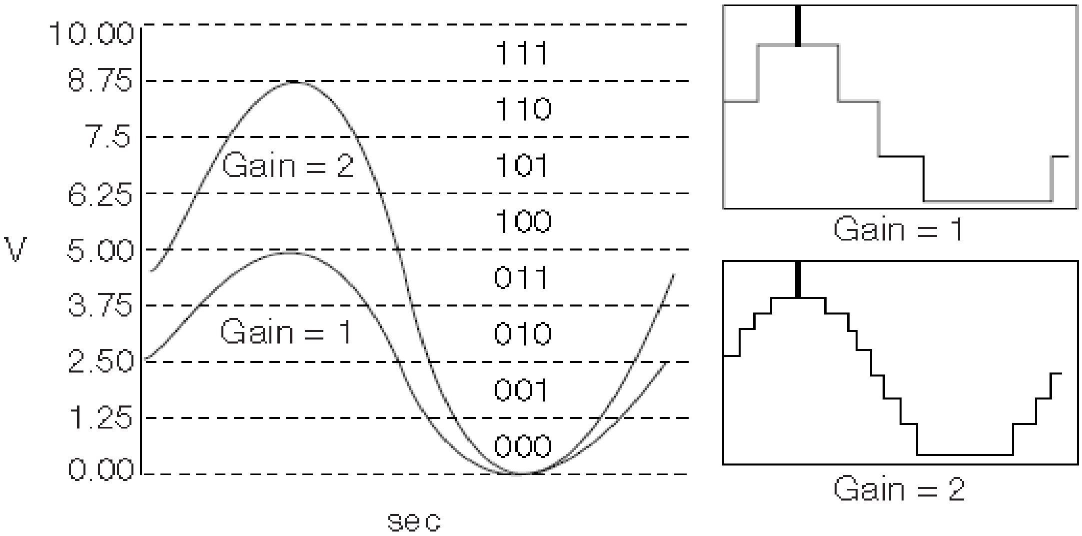



Figure 3.8: Effect of Gain over accuracy of the digitized signal

So the range, resolution, and gain available on a data acquisition device determine the smallest detectable [19] change in the input voltage. This voltage change represents one least significant bit (LSB) of the digital value which is called as the code width and that can be calculated by the formula as depicted below:

$$\text{Code Width} = \frac{\text{Voltage Range}}{\text{Amplification} \times 2^{\text{Resolution In Bit}}}$$

Hence the smaller the code width more accurately a device can represent the signal. In other words for better accuracy, the voltage range need to be small and resolution has to be as high as possible. The voltage range should be small in the sense it should be as close as possible to the signal range.

## E. Sampling frequency

One of the most essential elements of an analog input or analog output measurement system is the rate at which the analog to digital converter samples an incoming signal and generates the output signal. The scan rate, or sampling rate determines the speed of analog-to-digital (A/D) or digital-to-analog (D/A) conversion. By sampling too slowly will result into aliasing, which is a misrepresentation of the analog signal. To completely recover the continuous signal from its samples the sampling frequency should be at least twice the highest frequency present in the signal and this theorem is known as Shannon’s sampling theorem. The relationship between sampling frequency and signal reconstruction is represented in Figure 3.9.

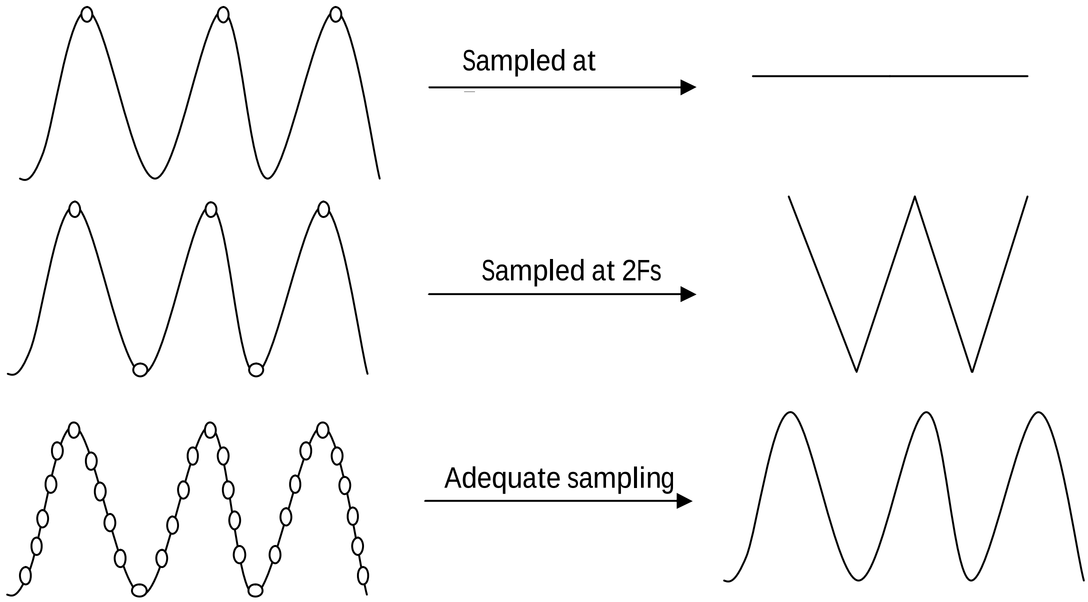



Figure 3.9: Effect of sampling frequency upon the reconstructed signal

From the above analysis it is clear that, the Nyquist theorem provides a starting point for the adequate sampling rate which is greater than two times the highest frequency component in the signal. But unfortunately, this rate is often inadequate for practical purposes. Physical-world signal often contain frequency component which lies above the Nyquist frequency and are erroneously aliased and added to the components of the signal which are sampled accurately, producing distorted sampled data. Hence, for practical purposes, sampling is usually done at several times the maximum frequency which is around 5 to 10 times is in real time environment.

**F. Connection of ground terminal**

To produce accurate and noise-free measurements an appropriate input configuration should be made according to the corresponding signal source. The type of different signal sources or different input configuration varies in accordance with the ground connection which is represented below.

- Type of signal source: There are two types of signal sources according to the connection of ground terminal as:

- **Grounded signal source** - A grounded source is the one in which the voltage signals are referenced to a system ground, such as the earth or a building ground.
- **Floating signal source** - In a floating signal source, the voltage signal is not referenced to any common ground, like the earth or a building ground.

➢ Types of Measurement Systems: Three different types of measurement systems are there according to connection of ground terminal. They could be:

- **Differential Measurement System –** Differential measurement systems are similar to floating signal sources in which the measurement is done with respect to a floating ground which is different from the measurement system ground. Neither of the inputs of a differential measurement system is tied to a fixed reference. An ideal differential measurement system will respond only to the potential difference between its two terminals, the positive and negative inputs where as it rejects or does not accepts common-mode voltage.
- **Referenced Single Ended Measurement Systems** - A referenced single-ended measurement system measures voltage with respect to the signal ground which is directly connected to the measurement system ground.
- **Non-Referenced Single Ended Measurement Systems** - In a Non-Referenced Single Ended measurement system, all measurements are still made with respect to a input reference but the potential at this node can vary with respect to the measurement system ground. A single-channel Non-Referenced Single Ended measurement system is same as a single-channel differential measurement system.

From the above discussion it is clear that a grounded signal source can be best measured with a differential measurement system. If the grounded signal source will be connected with a ground-referenced measurement system then ground loop will appear which is illustrated in Figure: 3.10. Here the measured voltage $V_m$ is the sum of the signal voltage, $V_g$, and the potential difference, delta $V_g$ that exists between the signal source ground and the measurement system ground. Due to the ground-loop which arises because of potential difference between the two grounds causes a ground-loop current to flow in the interconnection.

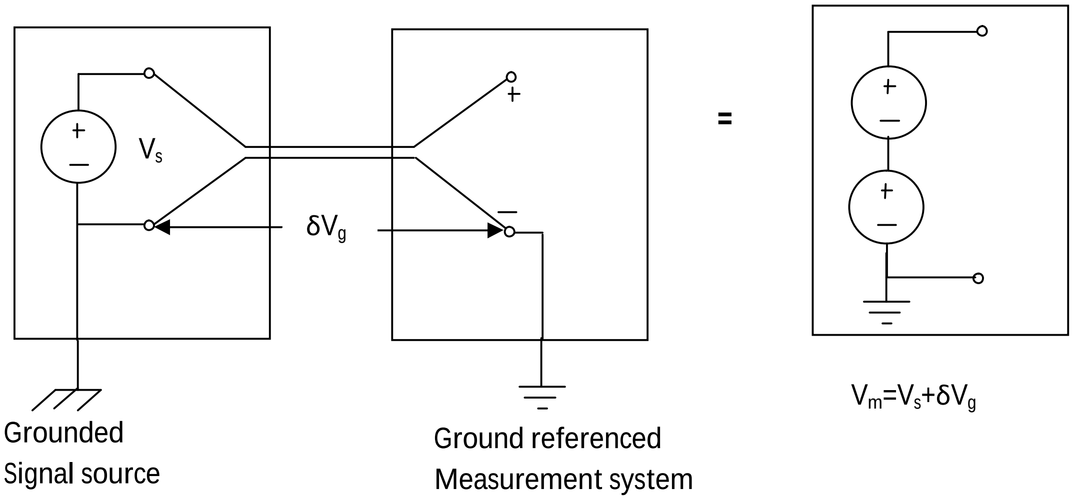



Figure 3.10: Illustration of ground loop in the referenced measurement system

But in the case of differential and non referenced measurement system differences between references of the source and the measuring device appear as common-mode voltage to the measurement system, and are subtracted from the measured signal which is illustrated in Figure: 3.11.

The floating signal sources can be measured with both differential and single-ended measurement systems without any possibility of ground loop.

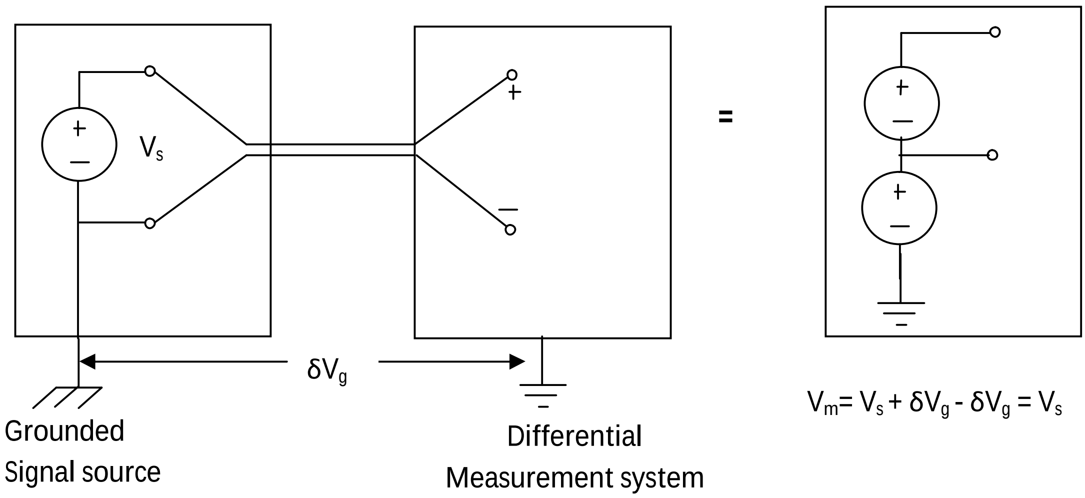



Figure 3.11: Illustration of Differential measurement system

At the outset there should be a thorough understanding of nature of the signal, the configuration that is being used to measure the signal, the capability of data acquisition hardware which is being used and the impact of the environment surrounding the system. Based on this information, it can be decided about the requirement of signal conditioning hardware, sampling frequency, range of the acquired signal to be chosen and the selection of input configuration according to the connection of ground terminal.

## 3.8 Data Acquisition Software

Data acquisition software can be the most critical factor in obtaining reliable, high performance operation. Software transforms a personal computer and data acquisition software into a complete acquisition, analysis, and display system [16-18].

There are two types of data acquisition software as described earlier.

1. Driver level software
2. Application level software

The driver level software is low level software, which does the following operations:
Hardware detection (DAQ boards)

- Assigning device numbers
- Board Calibration
- Board Configurations e.g. differential or single-ended

The purpose of having a appropriate application level software is as following:

- Acquire data at a specified sampling rate
- Acquire data in the background while processing in the foreground
- Stream data to and from disk

The different types of application level data acquisition software are

- Custom programmable software
- Pre-built data acquisition software packages.

Programmable software involves the use of a programming language, such as

- C++, Visual C++
- BASIC, Visual Basic + Add-on tools (such as VisuaLab with VTX)
- Fortran
- C#
- MATLAB

The advantage of writing custom software for data acquisition is that the programme has ultimate flexibility in what the software does. The disadvantage is that this is complex and time consuming. The alternative way is to use data acquisition package software which does not require traditional programming. The application can be on

- LABVIEW
- Measurement Studio

## 3.9 Data acquisition using LABVIEW

LABVIEW is a graphical programming language that uses icons instead of lines of text to create applications. That is the reason why it is very popular. It has variety of application. It covers the area like data acquisition, signal processing, control and automation etc [16-18].

### 3.9.1 Problems regarding LABVIEW Package

Basically LABVIEW is a trademark of National Instruments. That means it is not an open software. So we cannot use the software any where we want at any time. If we want to buy the software itself it will exceed the cost of DAQ card which will spoil all of its merit. Another solution to this problem is we have to use third party software, where we will use the properties of LABVIEW. To do this we need to create a .dll or some library file, which will be inherited by the third party software.

### 3.9.2 Executable file in LABVIEW

The best solution to the above problem is that we can luckily build an executable file in LABVIEW itself. As a result we can able to perform data acquisition process even if we don’t have the LABVIEW or Measurement Studio environment with us.

There are two types of files that can be created as

i. .Exe file (Run temporarily)
ii. Installer file (Install permanently)

Hence there are some obvious merits of this of this executable file as:

- It is very easy to install within some minutes.
- It can be protected with password for security reason.
- Inherit almost all features of LABVIEW at the time of designing it.
- Takes very little start up time as compared to LABVIEW.
- It Need very less space to install or to run temporarily.

Despite these merits there are some demerits involving with it as:

- Cannot able to modify the software according to the change in the requirement at any time
- Does not provide the design window interface.
- Does not give any information about connection of channel in case of multichannel data acquisition system

## 3.10 Methodology

### 3.10.1 Hardware implementation upon DAS

Several sensors are located at different places to acquire the signal from artillery unit. In the present case a Plotter is used to plot the data graphically during the course of firing. The necessary control signal is fed into the artillery unit from the control panel. The same signal is also brought to the signal test bench. The plotter is connected to the signal test bench where, the data (Control signal) is printed graphically. Block diagram of the entire process is shown in Figure 3.12.

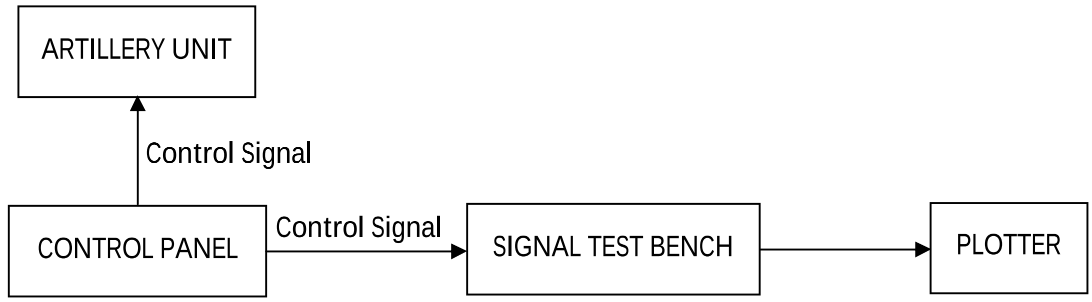



Figure 3.12: Data acquisition setup using Plotter

A “connection panel” is designed and connected after the signal test bench such that, the signal tests bench data comes to connection panel instead of directly feeding to the plotter. The modified process with connection panel is shown in Figure 3.13.

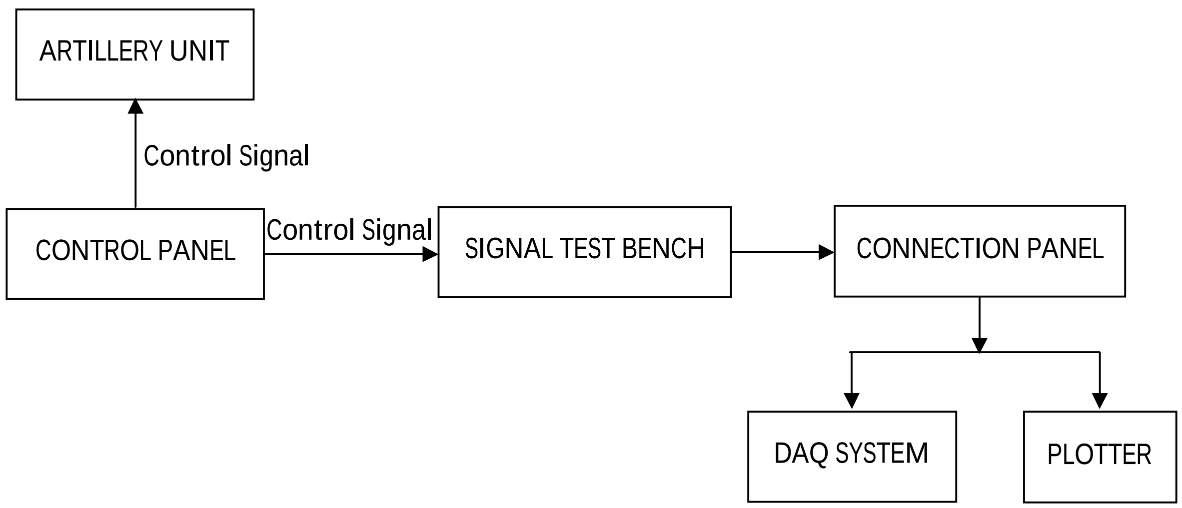



Figure 3.13: Modified data acquisition setup using DAQ system

The output of connection panel is connected to developed data acquisition system and plotter in parallel such that the data can be stored in PC as well as plotted in a paper. The connection panel is an input output circuit board which is responsible for simultaneous output of data acquisition hardware and plotter. The top view connection panel is shown in Figure 3.14.

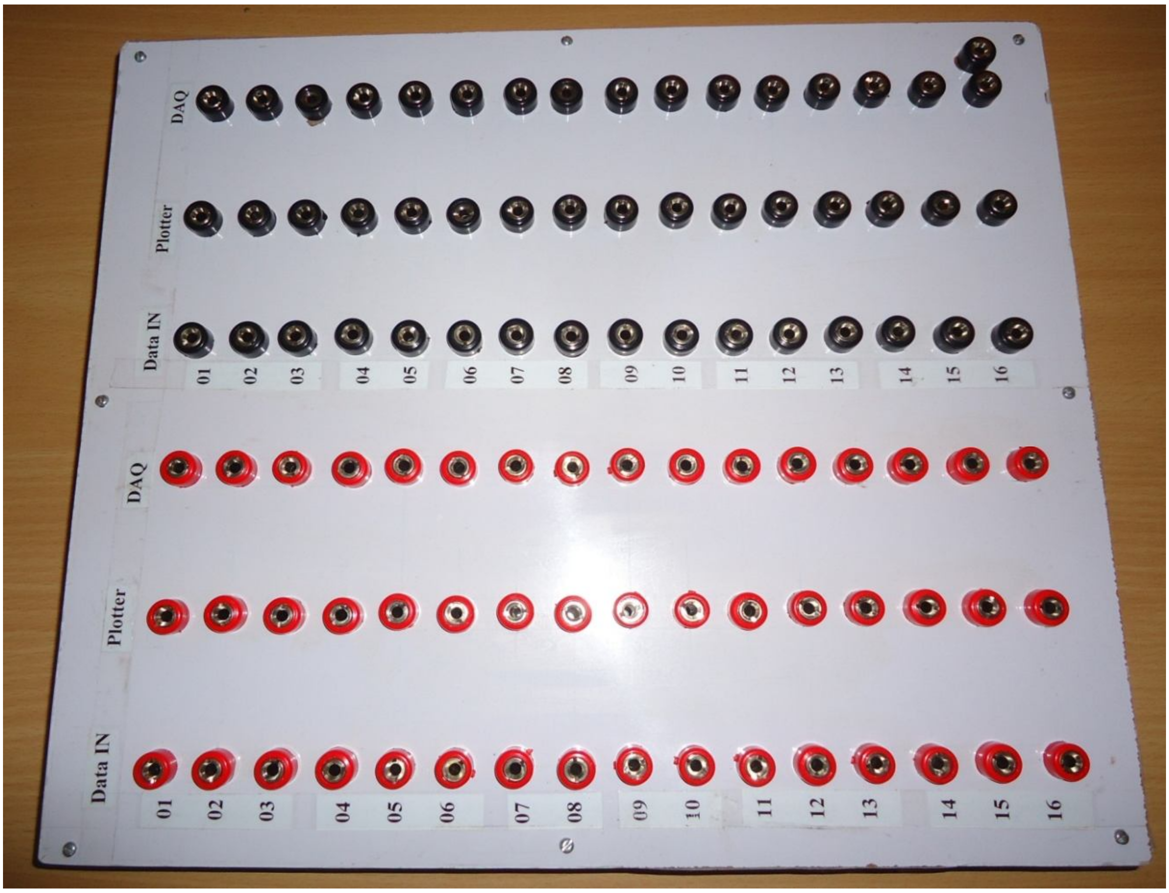



Figure 3.14: Top view of the connection panel

The connection panel constitute of three sets of port as:

- Control signal Input port
- Plotter output Port
- DAQ output Port

In addition to that each set has sixteen number of port which corresponds to sixteen number of channel in serial. All the three sets defined are connected in parallel basis for each channel. There is a common ground for the entire set of channel.

An USB based data acquisition card, “NI 6218” is used here for data acquisition purpose. The data acquisition card along with the terminal pins is shown in Figure 3.15.


Figure 3.15: NI DAQ card 6218

The Data acquisition card shown in the figure is chosen according to the requirement for this project. Some of the essential specification of the DAQ card is outlined here.

Table 3.1: Essential specifications of the NI DAQ 6218

| PARAMETER | VALUE |
|---|---|
| Number of channel | 16 differential<br>32 single ended |
| ADC Resolution | 16 Bit |
| DNL | No missing code guaranteed |
| Sampling rate | Maximum- 250 KS/s<br>Minimum – 0 KS/s |
| Maximum Voltage | 10V |
| Maximum voltage range | +10V<br>-10V |
| I/O FIFO size | 4095 sample |

For real time application purpose the above data acquisition card is designed according to its durability point of view. It is housed inside a robust box which is covered by a transparent material. All the terminal pins of data acquisition card are replaced with banana female port which becomes very easy to connect with tight fitting. A top view look of the designed data acquisition system is shown in Figure 3.16.

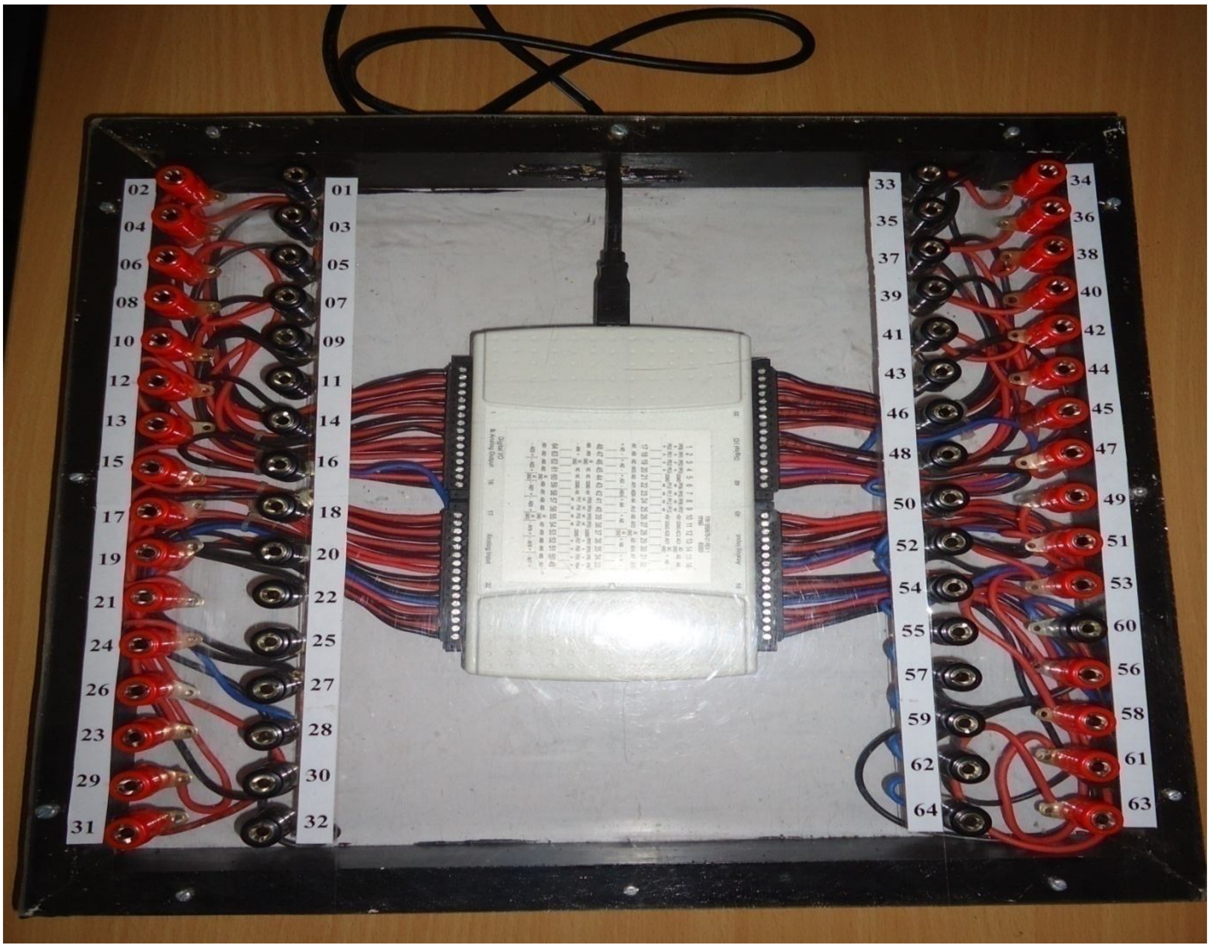



Figure 3.16: Designed data acquisition card

### 3.10.2 LABVIEW Implementation on DAS

Basically LABVIEW is a trademark of National Instruments. Hence it is well compatible with the NI DAQ 6218 card supporting most of the functionality. LABVIEW is a graphical programming language that uses icons instead of lines of text to create applications. In this project LABVIEW is implemented as application software to control the NI DAQ 6218 card. In addition to that the data can be stored for future reference. A user friendly front end is designed in a simplified manner included with various options which is shown as in Figure3.17.

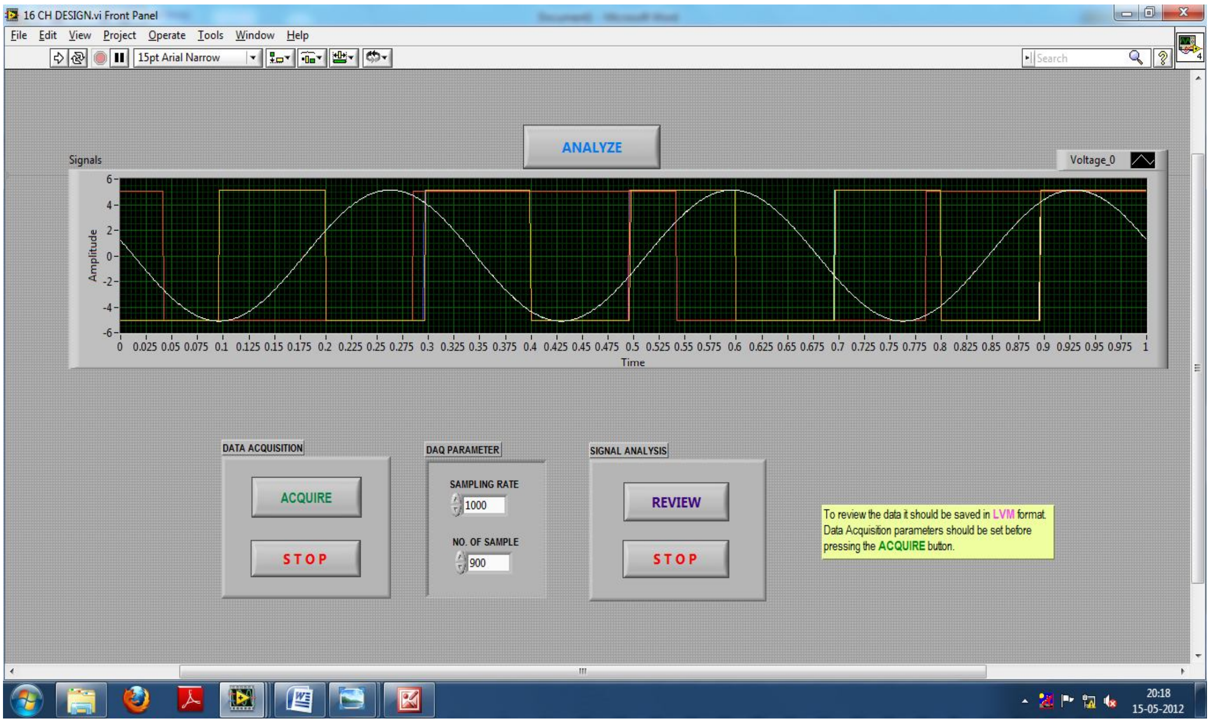



Figure 3.17: Front end design of MAIN MENU window for DAQ using LABVIEW

The Figure shows the design of the MAIN MENU window for the entire data acquisition process. In this design when the acquire buttton will be pressed a new page will be opened for data acquisition purpose. On pressing the review button the saved data will be retrived for verification purpose. The analyze button should be pressed after the review

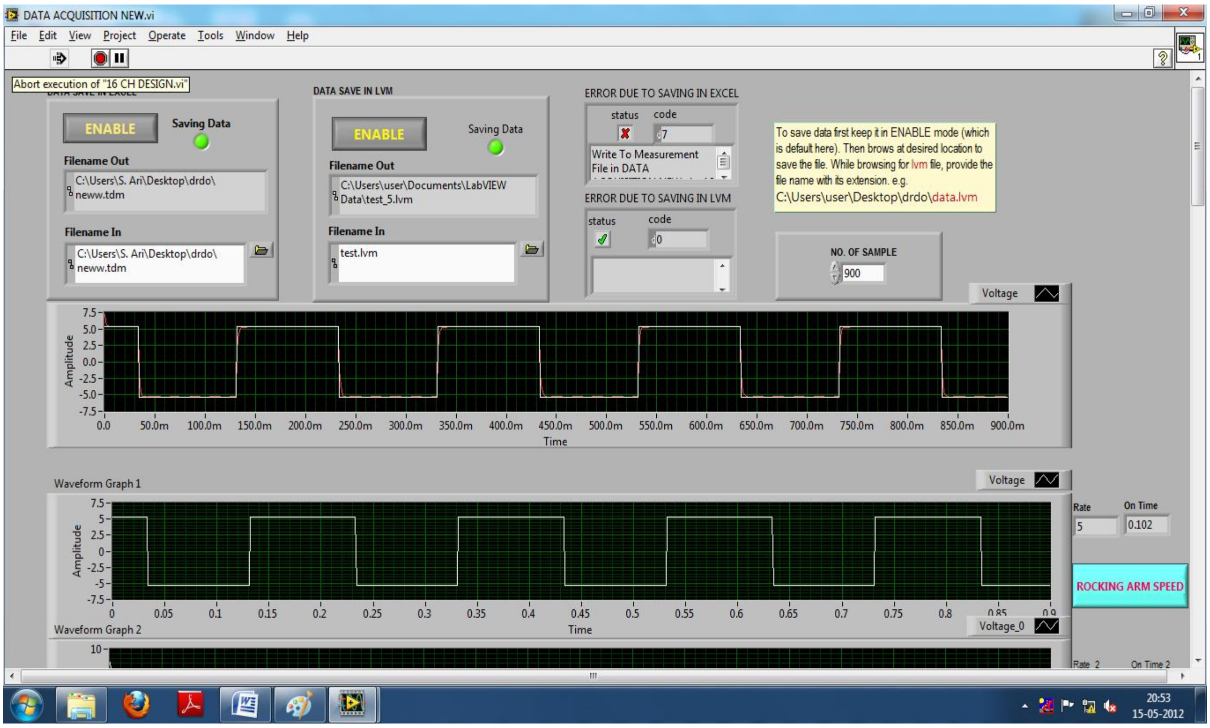



Figure 3.18: Front panel view of data acquisition process using LABVIEW

button where the signal will be analysed to extract necessary information. The snap shot of Data acquisition appearance window is shown in Figure 3.18. Before pressing the acquire button from the main menu, the essential parameters regarding DAQ such as Sampling rate and Number of samples should be set according to the signal characteristerics. The block diagram design for the data acquisition process for sixteen channel is shown in Figure 3.19.

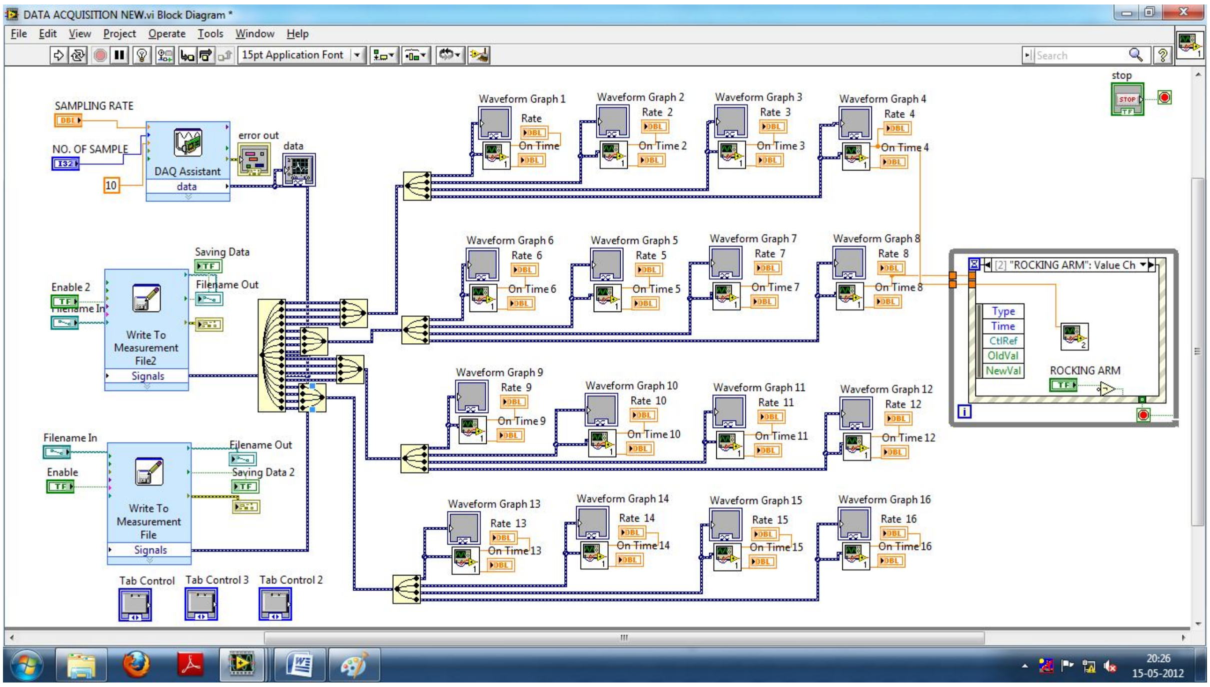
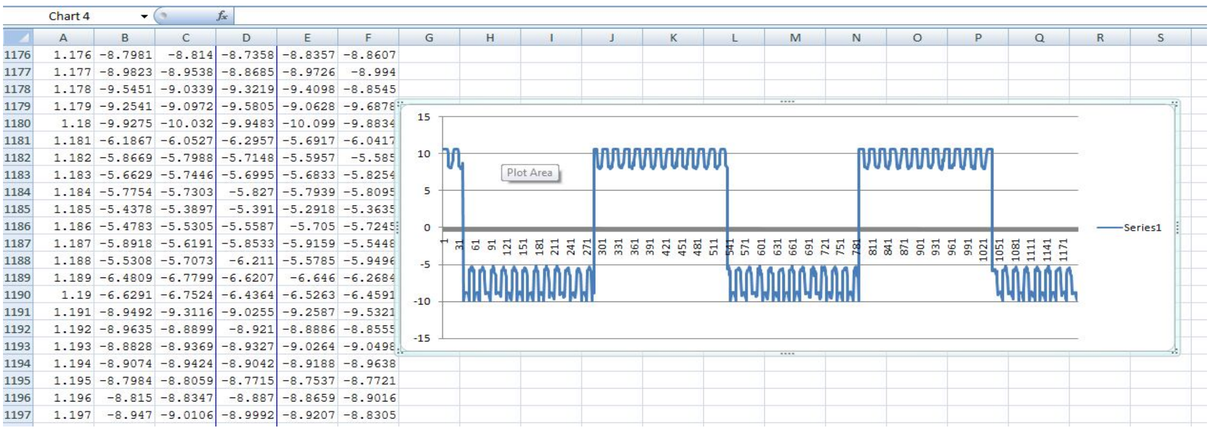



Figure 3.19: Block Diagram design for sixteen channel data acquisition process

In the data acquisition window the ENABLE buttons should be pressed to save the data in the excel sheet (.tdm file) or in LABVIEW measurement file lvm format. The file must be created by brwsing to a appropriate path before saving the data. The sixteen channel data stored in excel format is given in Figure 3.20.



| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1176 | 1.176 | -8.7981 | -8.814 | -8.7358 | -8.8357 | -8.8607 |
| 1177 | 1.177 | -8.9823 | -8.9538 | -8.8685 | -8.9726 | -8.994 |
| 1178 | 1.178 | -9.5451 | -9.0339 | -9.3219 | -9.4098 | -8.8545 |
| 1179 | 1.179 | -9.2541 | -9.0972 | -9.5805 | -9.0628 | -9.6878 |
| 1180 | 1.18 | -9.9275 | -10.032 | -9.9483 | -10.099 | -9.8834 |
| 1181 | 1.181 | -6.1867 | -6.0527 | -6.2957 | -5.6917 | -6.0417 |
| 1182 | 1.182 | -5.8669 | -5.7988 | -5.7148 | -5.5957 | -5.585 |
| 1183 | 1.183 | -5.6629 | -5.7446 | -5.6995 | -5.6833 | -5.8254 |
| 1184 | 1.184 | -5.7754 | -5.7303 | -5.827 | -5.7939 | -5.8095 |
| 1185 | 1.185 | -5.4378 | -5.3897 | -5.391 | -5.2918 | -5.3635 |
| 1186 | 1.186 | -5.4783 | -5.5305 | -5.5587 | -5.705 | -5.7245 |
| 1187 | 1.187 | -5.8918 | -5.6191 | -5.8533 | -5.9159 | -5.5448 |
| 1188 | 1.188 | -5.5308 | -5.7073 | -6.211 | -5.5785 | -5.9496 |
| 1189 | 1.189 | -6.4809 | -6.7799 | -6.6207 | -6.646 | -6.2684 |
| 1190 | 1.19 | -6.6291 | -6.7524 | -6.4364 | -6.5263 | -6.4591 |
| 1191 | 1.191 | -8.9492 | -9.3116 | -9.0255 | -9.2587 | -9.5321 |
| 1192 | 1.192 | -8.9635 | -8.8899 | -8.921 | -8.8886 | -8.8555 |
| 1193 | 1.193 | -8.8828 | -8.9369 | -8.9327 | -9.0264 | -9.0498 |
| 1194 | 1.194 | -8.9074 | -8.9424 | -8.9042 | -8.9188 | -8.9638 |
| 1195 | 1.195 | -8.7984 | -8.8059 | -8.7715 | -8.7537 | -8.7721 |
| 1196 | 1.196 | -8.815 | -8.8347 | -8.887 | -8.8659 | -8.9016 |
| 1197 | 1.197 | -8.947 | -9.0106 | -8.9992 | -8.9207 | -8.8305 |



Figure 3.20: Data stored in Excel sheet

The data is stored in .lvm format to retrive it for future analysis in graphical format.

During the data acquisition process some important parameters can be figured out immediately. The button should be pressed from the data acquisition window for a specific channel to observe the respective operation of the artillery unit as shown in the Figure 3.21.

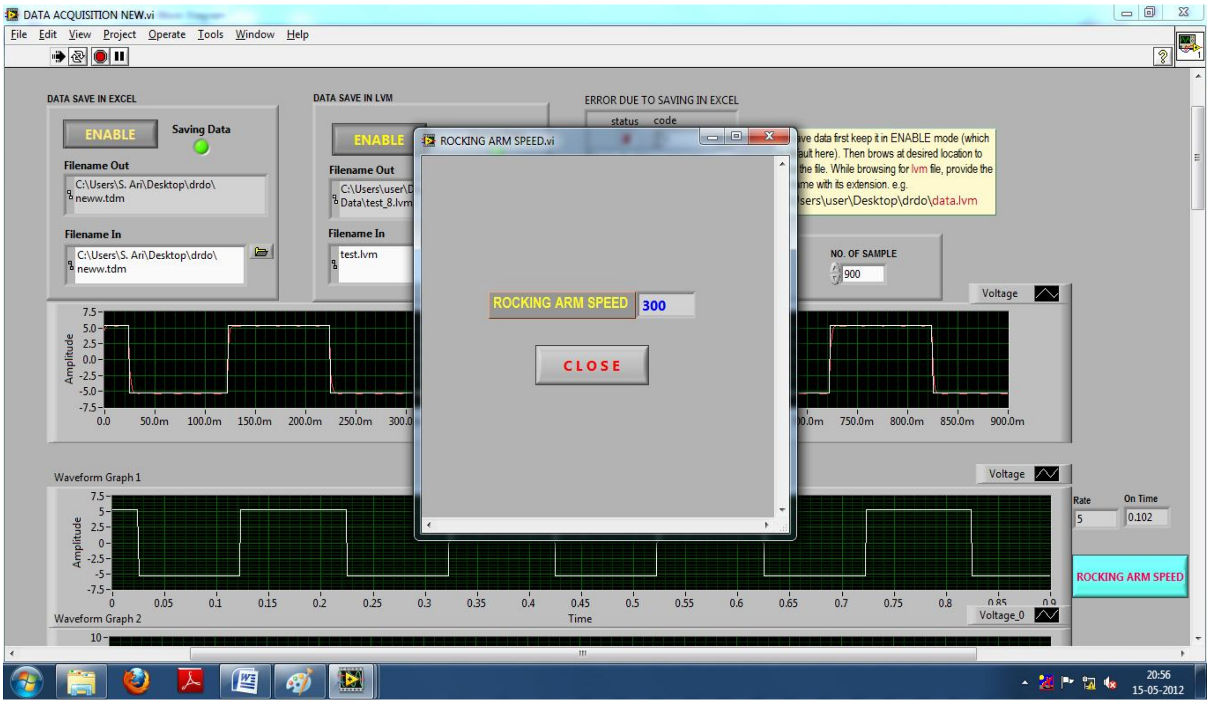



Figure 3.21: Parameter calculation during data acquisition process

The data after stored in .lvm format can be retrieved to analyse the operation of artillery unit. The data can be retrieved at an observable speed for a clear understanding of the entire process of operation of artillery unit, which is not possible during the course of data acquisition. The data retrieving process is given in Figure 3.22.

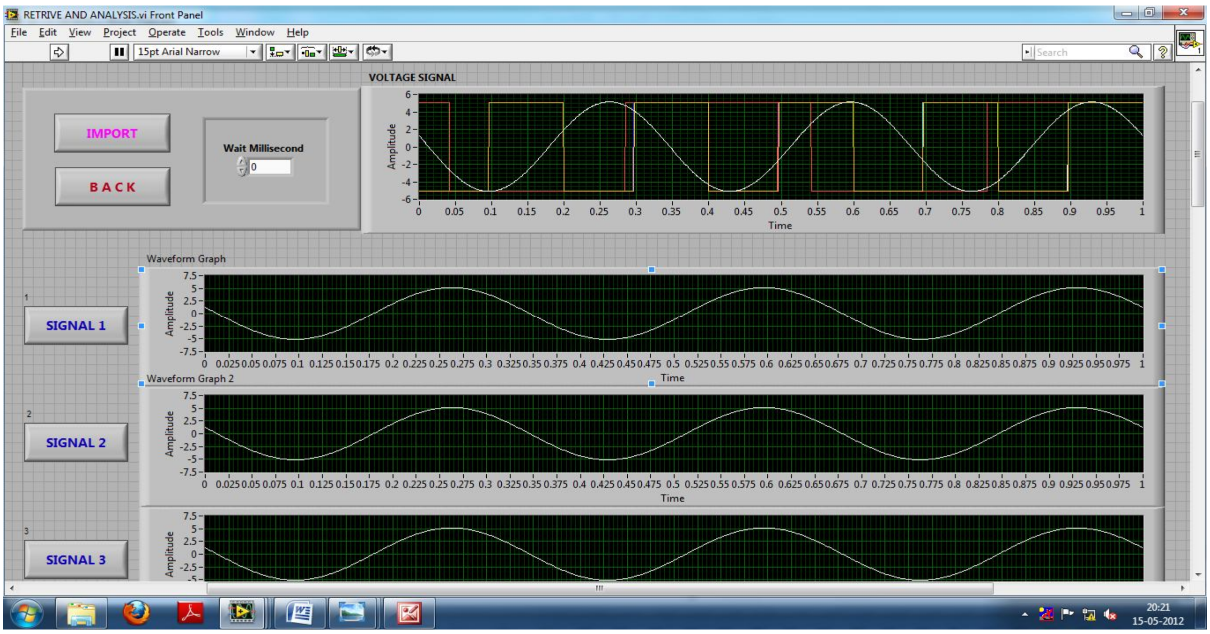



Figure 3.22: Data retrieving process using LABVIEW

While retrieving the sixteen channels stored data, the process can be stopped at required location of any signal to scrutinize for that period of time. The particular portion of the signal will be extracted out and can be analyze in more detail as shown in the Figure 3.23.

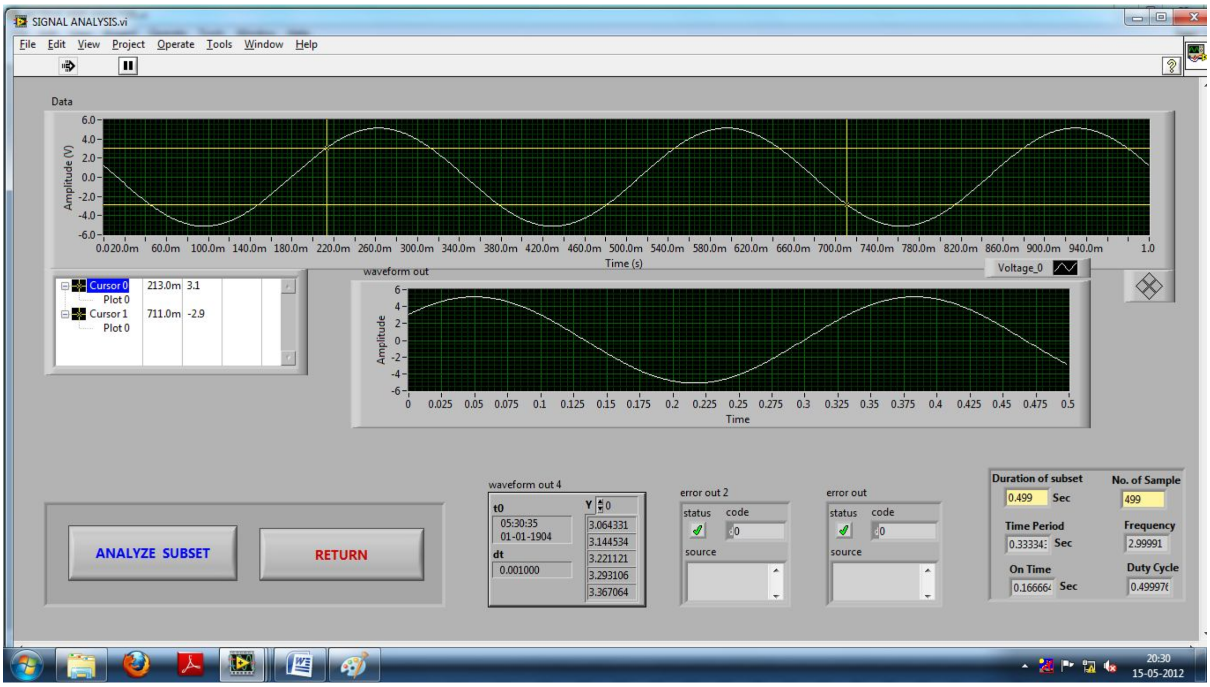



Figure 3.23: Signal analysis window

Any part of signal can be chosen with the help of two active cursors as shown in the Figure 3.23 to calculate some essential timing parameters like duration of the extracted portion, number of samples during that period, frequency, number of pulses etc.

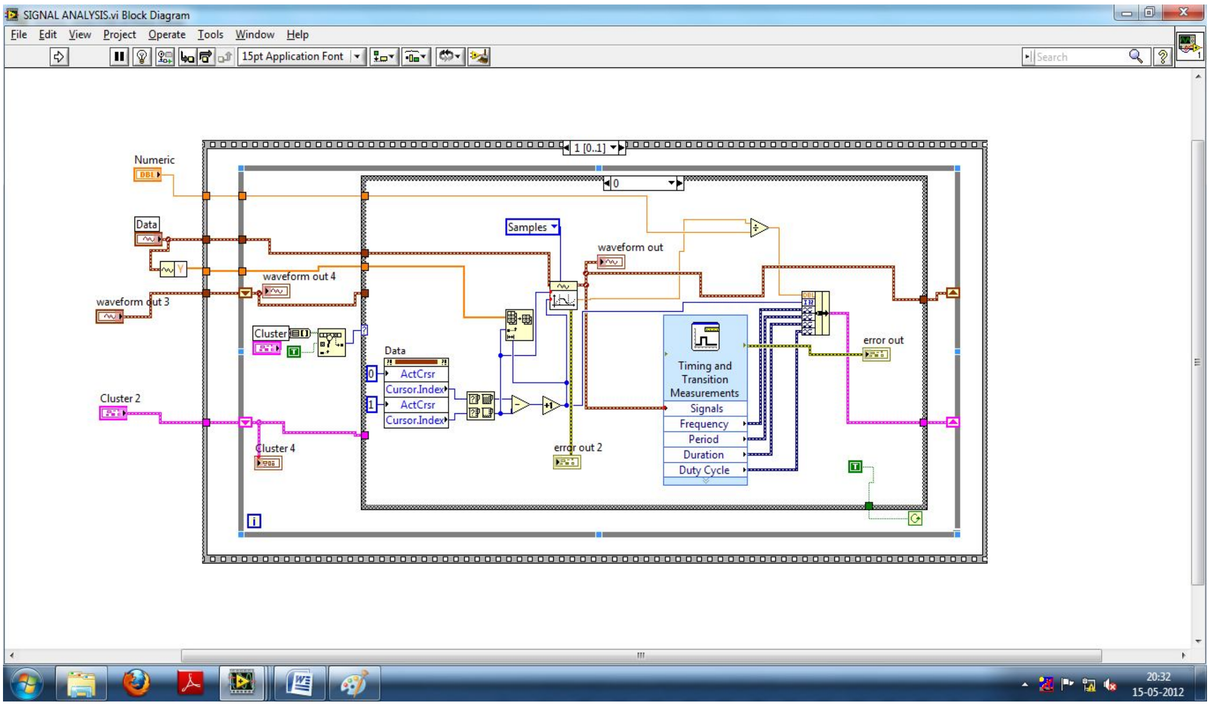



Figure 3.24: Block diagram design for the signal analysis window

The Figure 3.24 shows one case of design for signal analysis window where case structure and sequence structure are used. Two active cursers are used from the graph property to select any portion of the signal. Besides some of the windows discussed in this section, several other windows are designed to furnish the overall data acquisition process using LABVIEW. This design in LABVIEW is first tested in laboratory using the data generated from microcontroller based hardware and function generator. After the laboratory testing the data acquisition process is implemented in real time with the help of hardware and software unit as discussed in this section.

## 3.11 Results and Discussion

The data is acquired in real time with the help of designed data acquisition card, connection panel, Laptop and some connecting wires as shown in the Figure 3.25.

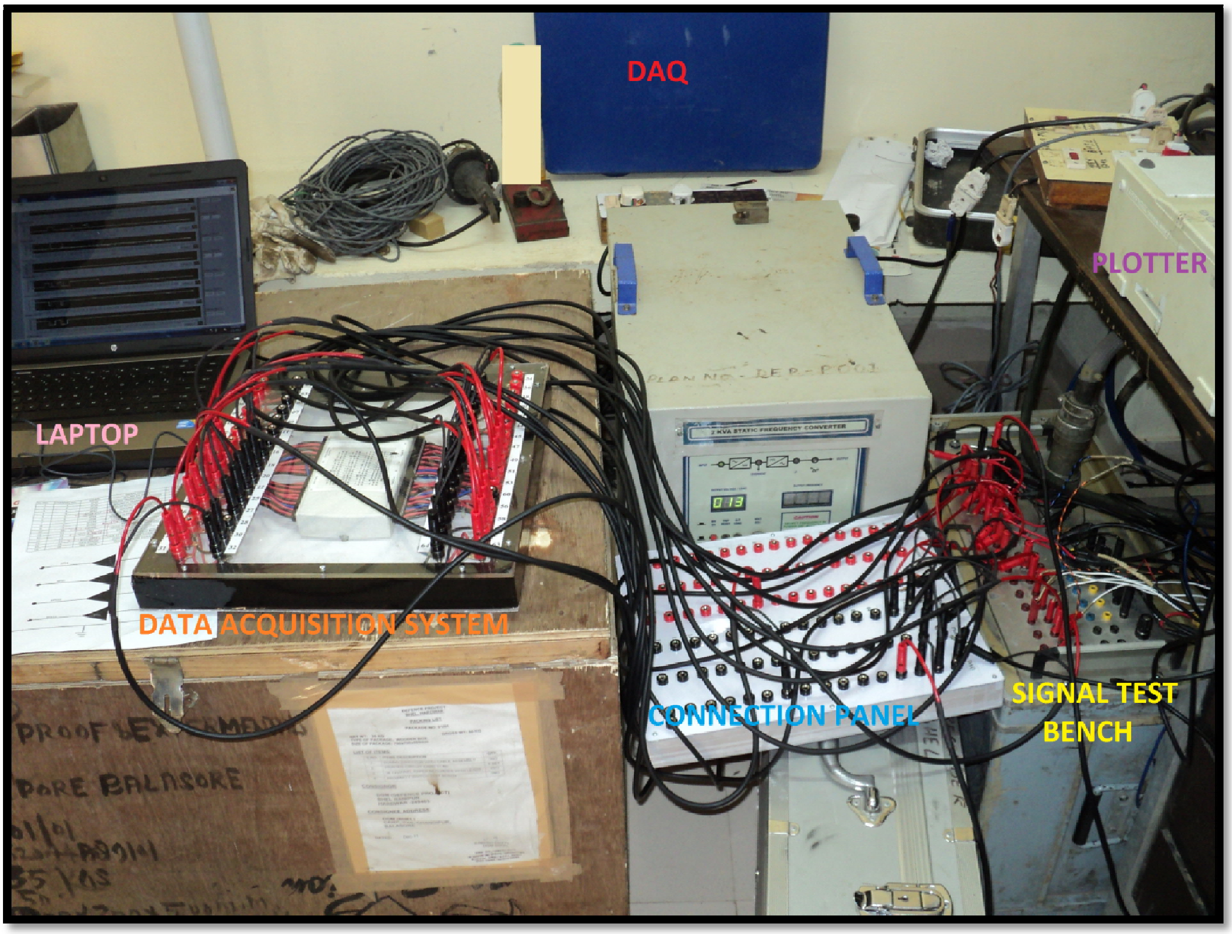



Figure 3.25: Data acquisition setup for real time testing

As discussed in this section, a similar type of data acquisition system setup was build for real time testing. The test bench output was connected to input port of connection panel. Then the 16 channel output signal from connection panel is fed to both designed data acquisition system and plotter in parallel. Figure represents the complete setup of data acquisition system. In this process the connecting wires made up of coaxial cables terminating with banana clips are used to avoid any interference. Here the USB based designed data acquisition system is used along with a Laptop which serves as an excellent portable data acquisition unit to be used at anywhere in a instant process. A snap shot of the data which are acquired from the artillery unit in real time is shown in Figure 3.26.

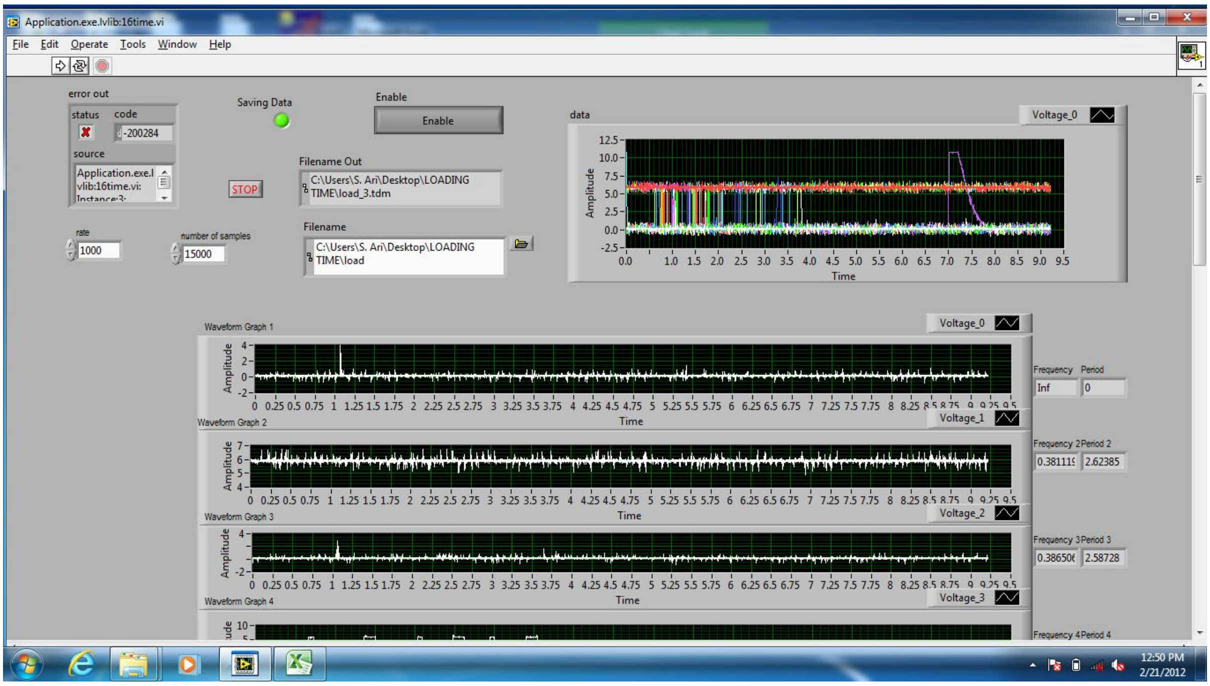


Figure 3.26 (a): Data acquired from artillery unit

Figure 3.26(b): Data acquired from artillery unit

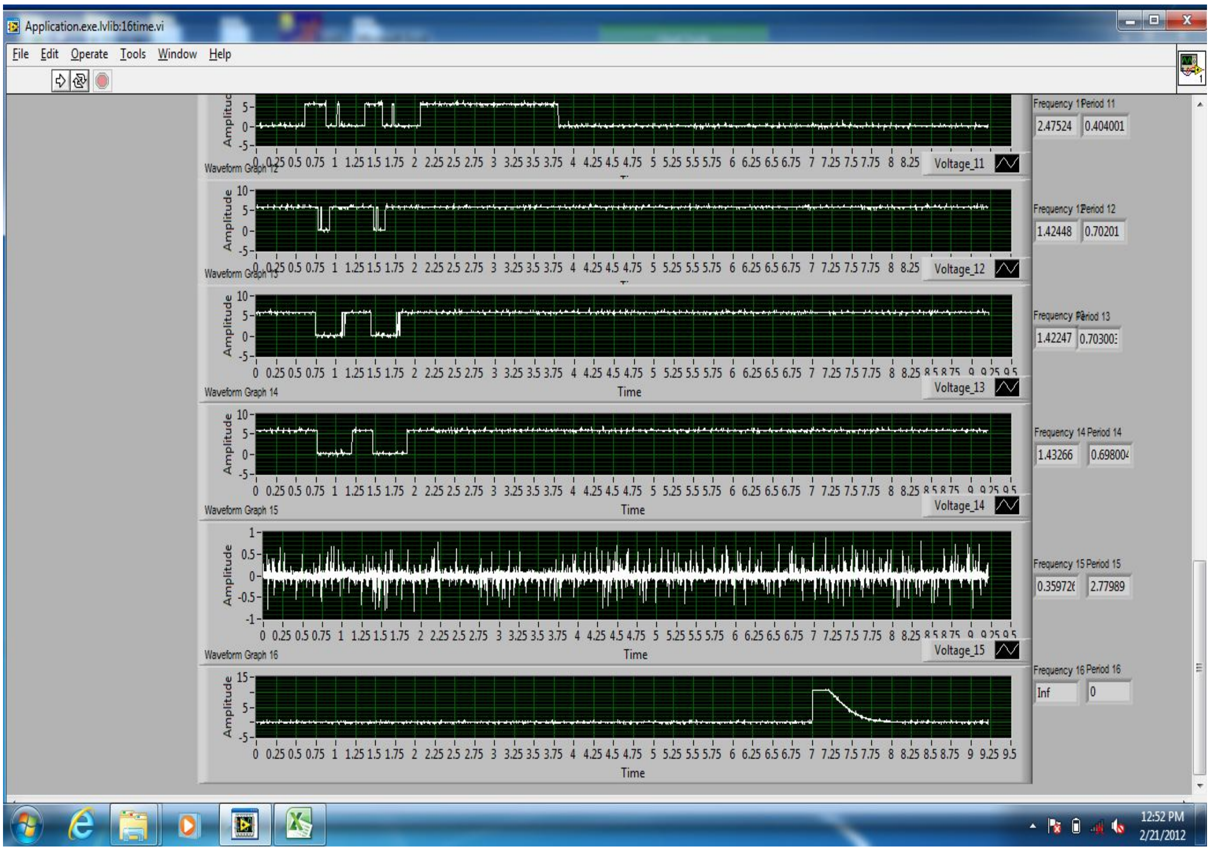


Figure 3.26(c): Data acquired from artillery unit

The data which are acquired as shown in the Figure is stored in excel sheet (.tdm file) as well as in LABVIEW measurement file (.lvm file) for future reference. Several parameters are calculated in a instant basis without involvement of man power which also avoids some possibility of errors like parallax error, calculation error etc.

Executable file is created for the above designed LABVIEW program which is to be run in a third party PC without installing LABVIEW software in it. Before running the executable file in the third party PC, "LABVIEW run time engine" (A Prerequisite software) has to be installed in it.

# *CHAPTER 4*

## ***ERROR DETECTION***
## ***IN ACQUIRED SIGNAL***

*Introduction*

*Theoretical background*

*Methodology*

*Result and discussion*

## 4.1 Introduction

Almost all signals acquired from the artillery unit are regular signals. They are all square wave voltage signals and each one having a specific period or frequency with specific amplitude. So any unwanted voltage signal comparable to the voltage level of original signal will be considered as error. As a result there will be a significant change in the regular frequency in the original signal.

To detect the above types of error, several traditional signal processing methods can be followed. In this scenario at first, the common signal processing method, FFT (Fast Fourier Transform) comes into picture. But in real time environment several high frequency noise components are present, although not so significant. In this project the interested type of signal is a square wave signal, which has infinite range of frequency in the frequency domain. Although the contribution of higher order frequency is less, still they can't be ignored completely.

Considering into above cases it will be a difficult task to implement fast Fourier transform as an error detection technique. After all the signal is not a stationary signal. So it is essential to find other signal processing tools for error detection. For non stationary signals, conventional Time-Frequency methods like, Wavelet transform (WT) method ant Short time Fourier Transform (STFT) method will be suitable choice. But for square wave signal the transient will arise very frequently due to the error in the signal, noise and the signal itself. Hence STFT method will not be a suitable choice here.

In this scenario, WT will be a better choice. WT provides multiple resolutions in frequency and time and hence becomes much efficient to analyze the transient behavior of signal. So the application of STFT and the Power Spectral Density (PSD) method to the transformed signal will be a better approach for online error detection.

## 4.2 Theoretical Background

### 4.2.1 Discrete Wavelet Transform (DWT)

The wavelet transform is a recently developed mathematical tool that provides a non-uniform division of Data or signal, into different frequency components, and then studies each component with a resolution matched to its scale [24]. So Wavelet analysis is an approach which decomposes a time domain signal into components in different time windows and different frequency bands and presents the resulting information in the form of a surface in the time-frequency plane.

Wavelet transform decomposes a signal into a set of basis function. These basis functions are called wavelets. Wavelets are obtained from a single prototype m(t) called mother wavelet, by dilation and shifting [25-26].

So if a mother wavelet function is defined such that,

$$\Psi(t) \in L^2(R) \tag{1}$$

Then the mother wavelet can form a basis set denoted by:

$$\psi_{s,u}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-u}{s}\right) \tag{2}$$

Where u is the translating parameter and s is the scaling parameter. S is always greater than zero because, negative scaling is undefined. Now the continuous wavelet transform can be defined in terms of mother wavelet as given below.

$$Wf(s,u) = \int_{-\infty}^{\infty} f(t)\psi^*_{s,u}(t)dt \tag{3}$$

$$= \int_{-\infty}^{\infty} f(t)\frac{1}{\sqrt{s}}\psi^*(\frac{t-u}{s})dt \tag{4}$$

In the same way the inverse wavelet transform can be defined as:

$$f(t) = \frac{1}{C_\psi}\int_0^{\infty}\int_{-\infty}^{\infty} Wf(s,u)\frac{1}{\sqrt{s}}\psi\left(\frac{t-u}{s}\right)du\frac{ds}{s^2} \tag{5}$$

Where $C_\psi$ is defined as:

$$C_\psi = \int_0^{\infty}\frac{|\psi(\omega)|^2}{\omega}dw < \infty \tag{6}$$

Here $\psi(\omega)$ is the Fourier transform of mother wavelet $\psi(t)$.

The Fourier transform of a signal S (t) will be defined as

$$S(f) = \int_{-\infty}^{\infty} S(t)e^{-j2\pi ft}dt \tag{7}$$

So the Fourier transform is based on harmonic wave, where as the Wavelet transform is based on the mother wavelet. However the Fourier transform can only be defined for stationary signal, where the frequency will not vary with time [26].

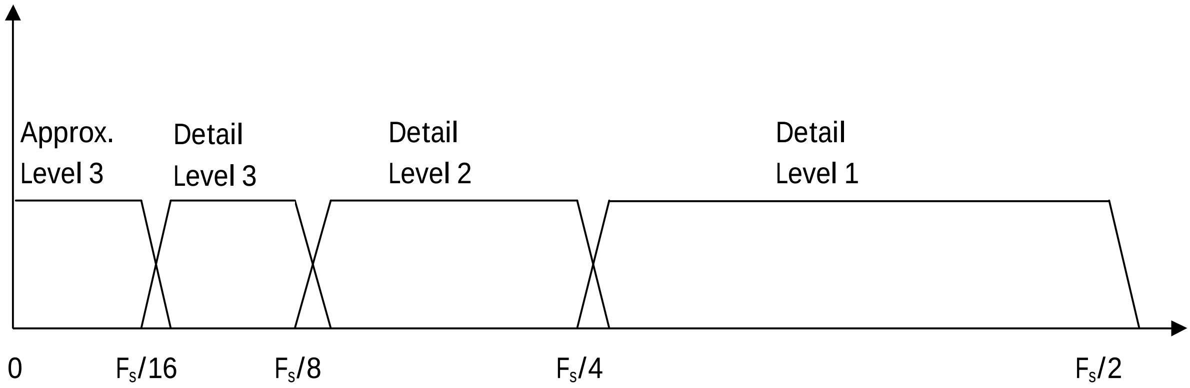



Figure 4.1: Frequency range coverage of detail and approximate level approximation

The coverage of frequency band for a three level decomposition process is shown in Figure 4.1. The frequency response of the filters of higher order mother wavelets are more ideal. Hence the overlapping of frequency bands of higher order Wavelet is less as compared to lower order. To obtain wavelet decomposition process a dyadic analysis filter bank is to be constructed, that decomposes a broadband signal into a collection of successively more band limited components.

A 2-level filter bank structure is shown in Figure 4.2. At each level, the low-frequency output of the previous level is decomposed into adjacent high- and low-frequency sub bands by a high pass (HP) and low pass (LP) filter pair. Each of the two output sub bands is half the bandwidth of the input to that level. The band limited output of each filter is maximally decimated by a factor of 2 to preserve the bit rate of the original signal.

### 4.2.2 Short Time Fourier Transform

Fourier transform cannot provide any information regarding temporal localization of frequency components. Hence to overcome from this problem STFT tries to solve it by introducing a sliding window, and hence in each slide, it emphasizes the signal at that time and suppresses the signal at other time. The window is designed to extract a small portion of the signal, which will be converted to frequency domain by taking the Fourier transform.

The STFT of a signal f(t) can be found out as:

$$Sf(u,\xi) = \int_{-\infty}^{\infty} f(t) w(t-u) e^{-j\xi t} dt \qquad (8)$$

Where, w (t-u) is the sliding window.

The energy density spectrum at time will be:

$$P(t,\xi) = |Sf(u,\xi)|^2 = \left| \int_{-\infty}^{\infty} f(t) w(t-u) e^{-j\xi t} dt \right|^2 \qquad (9)$$

Hence the energy density of STFT represents the spectrogram of function, which is generally represented in color plots. C.

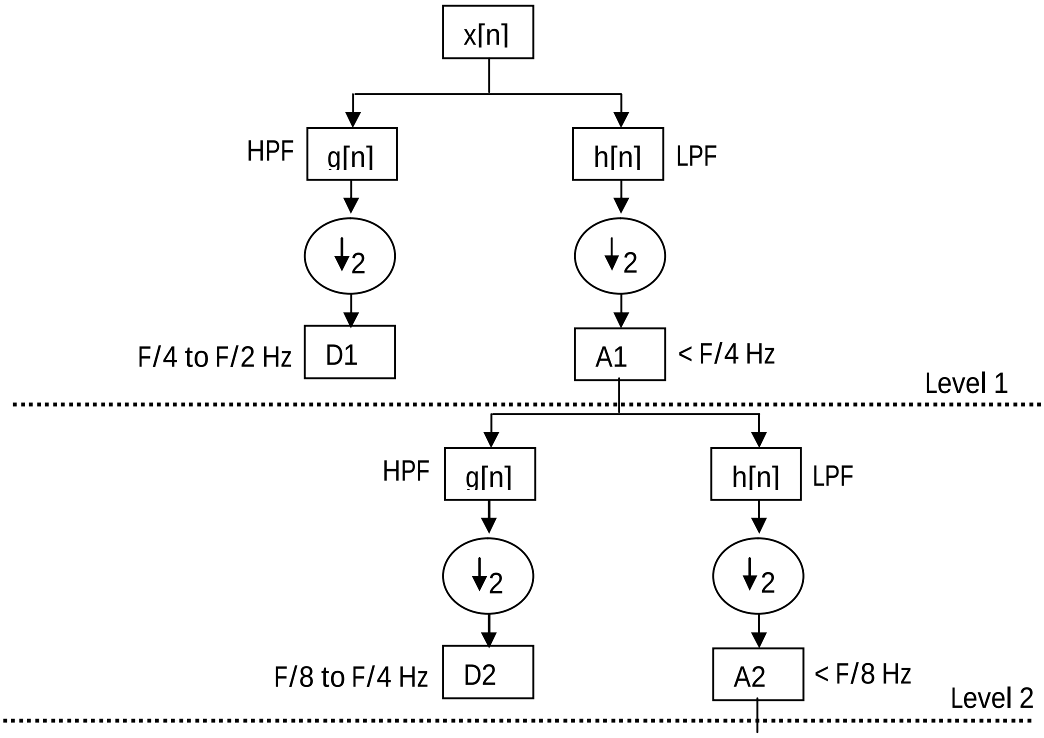



Figure 4.2: Wavelet analysis filter bank of DWT decomposition

### 4.2.3 Average Power

The square wave signal discussed here is continuous in time but produces discrete power spectrum. The waveform to be analyzed is a case of power signal that has infinite energy, but finite average power. To average power can be calculated by integrating the power spectral density curve (PSD). The PSD signifies the power per frequency in DB/HZ. So ultimately the area under PSD curve is the measure of the average power.

## 4.3 Methodology

The signals that are acquired get embedded with the noise during data acquisition process. The sources of error are due to the mechanical vibration of the equipments during firing. As a result some transient noise with spikes got embedded with the acquired signal. These noises are removed before the error detection process.

### 4.3.1 De noising of the Acquired Signal

As described in the section I, wavelet based decomposition method is applied to remove the noise present in the signal. The signals which are acquired which includes both correct and erroneous signal are decomposed into four levels using db1 as the mother wavelet. Although the frequency response of low pass and high pass filters of lower order wavelet (db1) is least ideal, still it is chosen as mother wavelet for this experiment. The reason is that, in this experiment square wave signals are used as test signals which contains infinite range of frequency in the frequency domain. So we don’t require any clear separation of frequency bands of signal to remove the noise. In addition to that db1 shows better results in terms of reproduction of corners and edges. Hence as described in the section II db1 will be a better choice for de noising of square wave signals.

Each level of the decomposed signal is threshold using a limiter. The depth of threshold limit at each level depends upon the amount of noise present at that level. Generally larger threshold limit is applied at higher order frequency band where the signal strength is less and noise strength is high. After threshold at each level, the signal is reconstructed back using wavelet reconstruct method.

### 4.3.2 Error Detection of De Noised Signal

The de noised signal which includes both error signal and correct signal are further wavelet decomposed for error analysis. This time db4 is used s mother wavelet and six decomposition level. The higher order detail levels are analyzed and compared for both error and correct signal. For a quick response about the presence of error, spectrograms of highest decomposition level of both signals are taken where the presence of error is found to be more pronounced. Further analysis is done by estimating the average power of each level of both of the signals and by making a comparison between corresponding levels and hence calculating the fault factor. The proposed method for de noising and error detection process is shown as block diagram in the Figure 4.3.

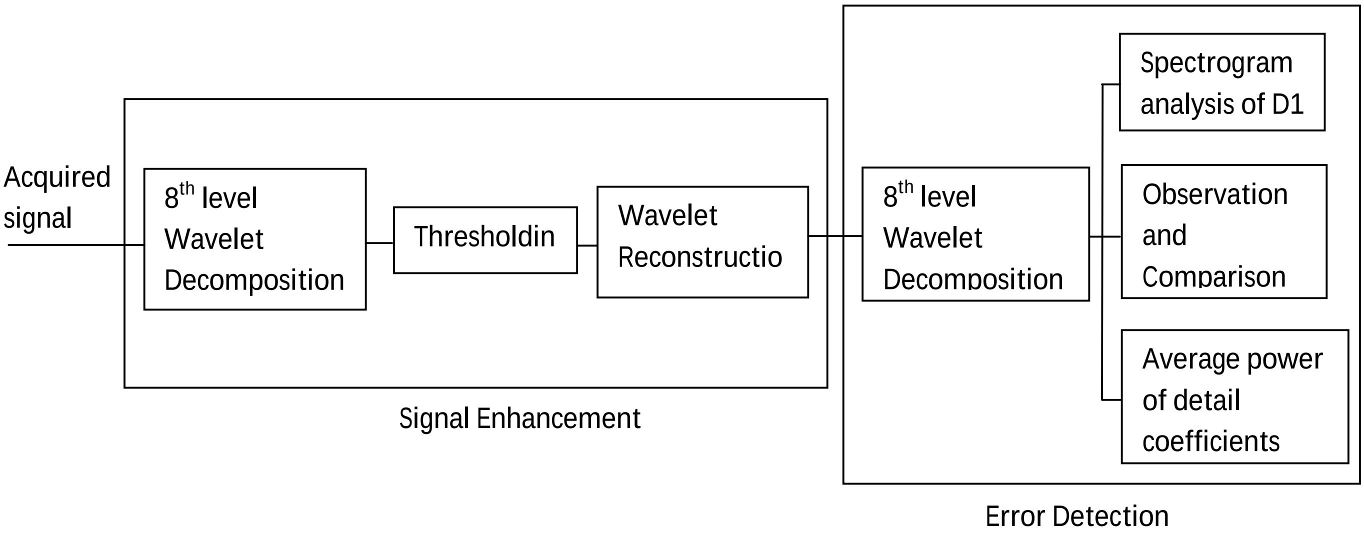



Figure 4.3: Block diagram of proposed method

### 4.3.3 Experimental Setup

A multichannel data acquisition system is designed to acquire the data. The detail about experimental setup for data acquisition system is described in section 3.11 using which the data is acquired in real time. Some essential parameters are to be considered during the data acquisition process. The important parameters would be sampling rate, number of samples, and voltage level etc. the range of these parameters selected for this experiment are:

- Sampling rate: 1 kHz.
- Number of samples: 15 K samples/sec
- Frequency range of acquired signal: 2-5 Hz

Selection of voltage range depends upon individual channel signal amplitude with an overall range of 100 mV – 10V.

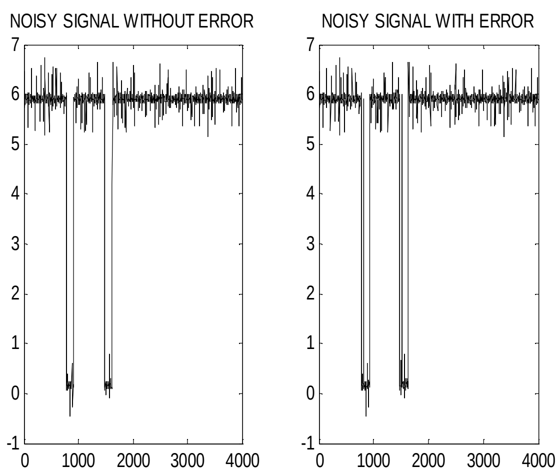



Figure 4.4: Captured signal with and without error

The signal that is captured is full of noise. The primary sources of noise are due to continuous vibration of mechanical equipments during firing, improper grounding, and lose connection which becomes looser after heavy vibration. A Sample of correct data and erroneous data being corrupted with noise are given in the Figure 4.4.

Various methods are applied to the acquired signal for error detection. But as shown in the figure 5, the presence of excessive noise bearing higher order frequency component dominant the presence of error. As the error is also having the higher order frequency component, it is difficult to detect it in the noisy environment. Hence it becomes essential to enhance the signal before detecting the error.

## 4.4 Results and Discussion

### 4.4.1 Signal Enhancement

In the real time system we don't have the signal void of noise. Hence we cannot compare the accuracy of noisy or de noised signal with the original signal. So before applying any signal enhancement method to the noisy signal, we need to evaluate the performance of the applied method using a model with a similar type of signal.

In the model, a signal is simulated similar to the signal that we have acquired through data acquisition process. Then the signal is added with white Gaussian noise of 5db 10db and 15db each time as given in Table 4.1. Then this noisy signal is enhanced using wavelet transform method and the performance is evaluated.

Table 4.1: Performance evaluation of wt method for de noising the signal

| INPUT SNR (db) | O/P SNR USING WT (db) |
|---|---|
| **14.8399** | 17.3973 |
| **9.9778** | 14.3149 |
| **5.4064** | 10.9017 |

From the result obtained in Table 4.1, it can be concluded that, the Wavelet transform method will be good approach towards de noising the acquired signal without any loss of information. In this method Wavelet transform is applied and decomposed the signal into five levels. Then the signal is reconstructed back after thresholding each level.

Now the acquired signal is de noised using the above described method, and the result is shown in the Figure 4.5.

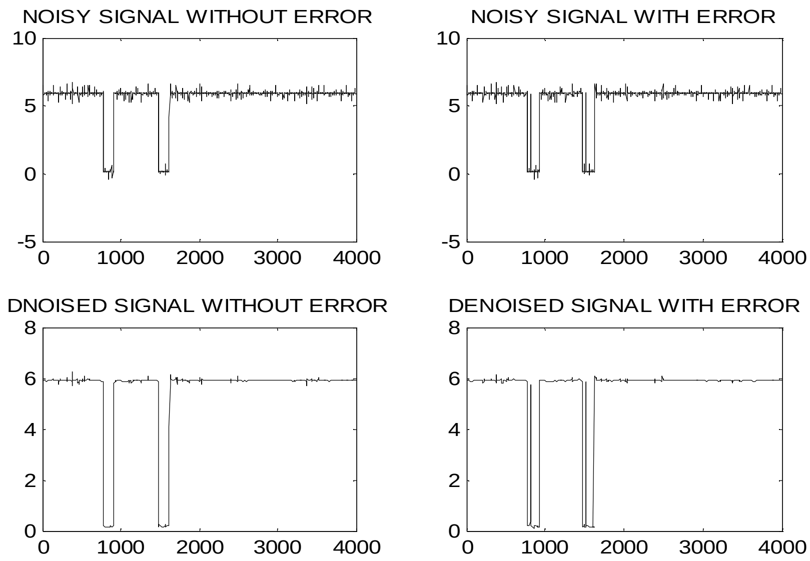



Figure 4.5: Resultant signal after de noising

### 4.4.2 Error Detection

For error detection in the de noised signal, Wavelet transform is applied over it to decompose it into different frequency level. In this experiment the frequency of the square wave signal varies from 2-5 Hz. Although the theoretical bandwidth of the square wave signal is infinite, the practical bandwidth will be same as 2-5 Hz. The signal is sampled at 1KHz. during data acquisition process. The signal is decomposed into five detail level by wavelet transform method. In this experiment, db1 is used as mother wavelet. The coverage of frequency band for each level is given in Table 4.2.

Table 4.2: Frequency coverage for each decomposed level of signal

| Decomposition Level | Frequency Range (Hz) |
|---|---|
| **Detail level 1** | 250 – 500 |
| **Detail level 2** | 125 – 250 |
| **Detail level 3** | 62.5 – 125 |
| **Detail level 4** | 31.25 – 62.5 |
| **Detail level 5** | 15.62 – 31.25 |
| **Detail level 6** | 7.812 – 15.62 |
| **Detail level 7** | 3.906 – 7.812 |
| **Detail level 8** | 1.953 – 3.906 |

The result of wavelet transform for both correct signal and erroneous signal are shown in the Figure 4.6 using db4 as mother wavelet. The presences of extra spikes are clearly visible in the detail level D1 through D4 in the erroneous signal which confirms the presence of error.

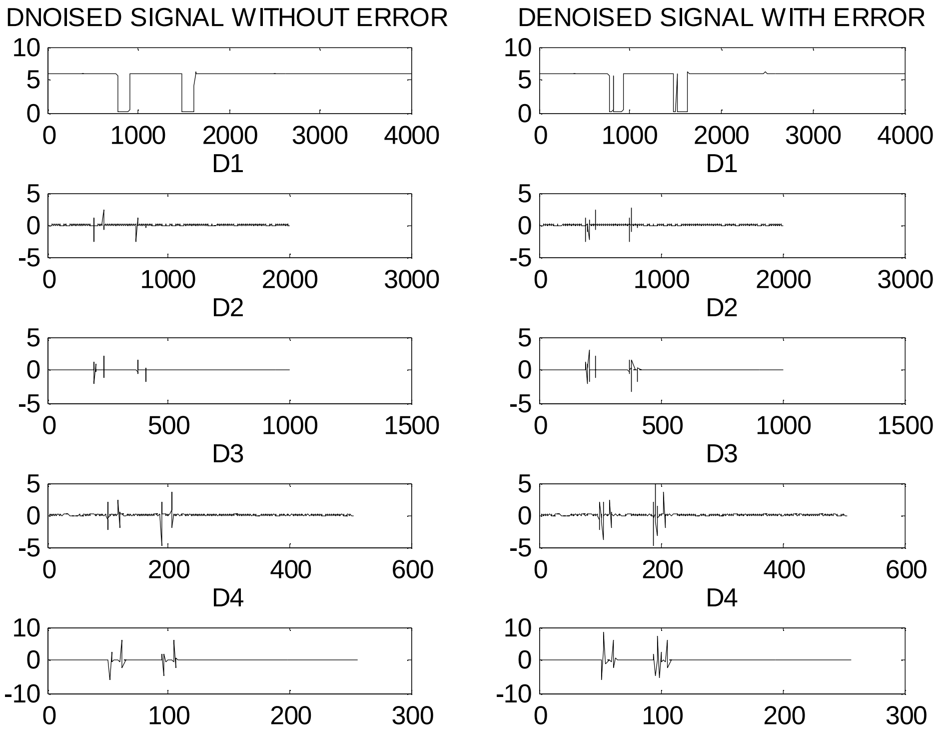



Figure 4.6: Detail levels of correct and erroneous de noised signal

The presence of error will be more pronounced if the spectrogram analysis of detail level will be taken as shown in the Figure 4.7.

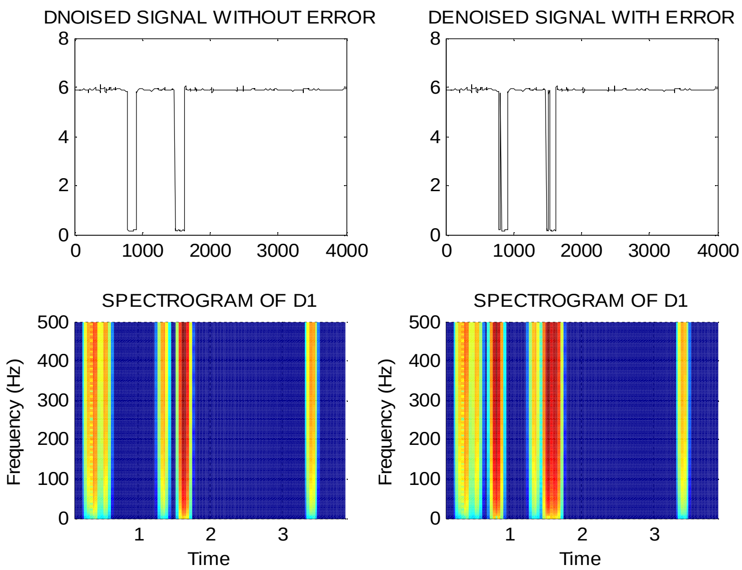



Figure 4.7: Spectrogram analysis of detail level 1

The spectrogram of detail level1 is taken after decomposing the signal using db1 as the mother wavelet. The difference is now clearly visible. Now the presence of error can be detected more instantly.

This process can be further preceded by taking the average power [23] of the detail level of both the signal and comparing the result, which is given in Table 4.3. The average power is calculated by taking the area under power spectral density curve.

Table.3: Average power for detail level of each signal

| Signal | D1 | D2 | D3 | D4 | D5 | D6 | D6 |
|---|---|---|---|---|---|---|---|
| Without error | .003 | .069 | .067 | 1.47 | 1.96 | 12.14 | 12.1 |
| With Error | .016 | .109 | .178 | 2.6 | 2.04 | 11.24 | 11.2 |

From the table it is clear that due to the presence of error, bearing higher order frequency content, the energy content of detail level D1 through D5 are comparatively higher for erroneous signal. Hence any significant change in the detail level energy content will indicate the onset of error.

# *CHAPTER 5*

## ***CONCLUSION AND FUTURE WORK***

## 5.1 Conclusion

Until quite recently most of the data gathering systems and industrial control procedures are based on electromechanical devices such as plotter and chart recorders. The capability to process and analyse data is rather limited (and in some cases error prone) unless one get access to a personal computer or laptop. In this project a PC based data acquisition system is developed successfully which is to be implemented to acquire the data from different sections of artillery unit during the course of firing. The “NI-6218” data acquisition card is designed into a robust configuration from the device longevity and its repeated application point of view. Several factors are considered while designing the data acquisition system like; secure connection, proper ground, adequate isolation etc. With the help of LABVIEW as application software, the data acquisition system is implemented with a user friendly front end. Sixteen prototype signals are generated in parallel from the microcontroller based hardware. These signals are acquired repeatedly with the help of designed data acquisition system to figure out any faults and mistakes regarding practical implementation. This developed data acquisition system is tested in real time where, it could successfully acquire and store the data for future reference. In addition to that several timing parameters are calculated and displayed during the course of acquisition thereby reduces the human efforts as well as completely avoids some common errors like parallax error or calculation error. The stored data is retrieved in graphical format and further analysed to detect any presence of error. In this case first, the acquired signals are enhanced using wavelet based technique and followed by detection of error of enhanced signal based on wavelet transform technique. Error detection method is evaluated using spectrogram analysis and shows the high performance for instant error detection in distorted signal. In addition to that, calculation of average power of each detail level provides a measure of effectiveness of error detection technique. Therefore the proposed technique could be used as a powerful tool for error detection in acquired signal in real time environment.

## 5.2 Future work

- The function generator cannot produce prototype signals of variable pulse width. Generation of test signals using microcontroller based hardware is somewhat lengthy and time consuming process. In this context other generator circuit can be used for recurrent testing of DAS in the laboratory.
- Online monitoring system can be implemented to the data acquisition system, using which the data acquisition process can be controlled and monitor remotely from office.
- For the highly noisy environment the performance of the proposed system may be decreased. Therefore development of a robust DAS can be a better choice.
- The error detection technique using wavelet transform method will be implemented in LABVIEW such that online error detection can be possible in an instant basis. In addition to that error detection process can be improved by implementing some recent classifier methods like signal processing and pattern recognition technique.

## ***REFERENCES***

## REFERENCES

[1] M.A. Mazidi, J.G.Mazidi, and R.D. Mckinlay, "The 8051 microcontroller and embedded systems using Assembly and C,", *McKinlay ,pearson education*, 2nd Edition,2007.

[2] Robert J. Matthys, "Crystal oscillator circuits",*Krieger publishing company Malabar, Revised edition, Florida.*

[3] N. Mathivanan,"Pc Based Instrumentation: Concepts And Practice," *PHI publication*, 2007

[4] Mike Tooley, "Pc based instrumentation and control," *Newnes Publication*, 2nd Edition, 2003

[5] Kevin James, "PC interfacing and data acquisition techniques for measurement instrumentation and control,", *Newnes Publication*.

[6] Bentley John P., "Principle of Measurement system," *Pearson education*,3rd Edition, 2005.

[7] HelfrickAlbet D. and Cooper William D., "Modern electronics Instrumentation and measurement system," *PHI Private Limited*, 2nd edition, 2007.

[8] R.A. Gayakward, "Opamps& Linear Integrated Circuits," *PHI Publication.*

[9] *Analog-to-digital Converter Design Guide*, Microchip Technology Inc., Chandler, AZ, 2004.

[10] T. Naqvi, Introduction to SyDe data acquisition systems and Lab VIEW, Oct. 29, 2004.

[11] G. W¨ostenk¨uhler, "Data Acquisition Systems (DAS) in General," Hochschule Harz, Wernigerode, Germany.

[12] *Transaction in Measurement and Control, vol. 2, Data Acquition*, Omega, Putman Publishing Company and Omega Press LLC, 1998.

[13] S. Li et al., "Continuous and real-time data acquisition embedded system for EAST," *IEEE Trans. Nuclear Science*, vol. 57, pp. 696-699, April 2010.

[14] Z. Hua, "Application of Lab VIEW in the design of data acquisition and signal processing system of mechanical vibration," presented at the 2011 *Int. conf. Mechatronic Science*, *Electric Engineering and Computer*, Jilin, China, Aug. 19-22, 2011.

[15] X. Wenyue and Y. Haiwen, "A development platform for complex data acquisition system," presented at the *10th ICEMT*, 2011.

[16] Conway, Jon, and Watts Steve, “A Software Engineering Approach to LAABVIEW,” *Prentice Hall*, 2003.

[17] Essick, John, “Hands on Introduction to LABVIEW for Scientist and engineers, *Oxford University Press*, 2008.

[18] Travis, Jeffery, Kring, and Jim, “LABVIEW for Everyone Graphical Programming Made Easy and Fun,” *Prentice Hall PTR*, 3rd Edition, 2006.

[19] *Data Acquisition and Signal Conditioning Course Manual*, National Instruments Corporation, North Mopac Expressway, Austin, Texas, USA, Aug. 2003

[20] *Lab-VIEW Analysis Concept*, North Mopac Expressway, Austin, Texas, USA, March 2004.

[21] *Data Acquisition Fundamentals*, National Instruments Corporation, April 2002.

[22] *Signal Conditioning Fundamentals for PC-Based Data Acquisition Systems*, National Instruments Corporation, Nov. 1997.

[23] J. Cusido, L. Romeral, J.A. Ortega, A. Garcia and J.R. Riba, “Wavelet and PDD as fault detection techniques,” *Electric Power Systems Research*, vol. 80, pp. 915-924, 2010

[24] Mudathir Funsho Akorede and James Katende, “Wavelet Transform Based Algorithm for High- Impedance Faults Detection in Distribution Feeders,” *European Journal of Scientific Research*, vol. 41 No.2, pp. 238-248, 2010.

[25] Neelam mehala and Ratna dahiya, “Rotor Faults Detection in Induction Motor by Wavelet Analysis,” *International Journal of Engineering Science and Technology,* vol. 1, pp. 90-99, 2009.

[26] S.G. Mallat, “A Wavelet Tour of Signal Processing,” second edition, *Academic Press*, 1998.

[27] NI developer zone: Introduction to data acquisition. [Online]. Available: http://www.ni.com/white-paper/3536/en

[28] The 8051/8052 Microcontroller: [Online] Available: http://www.8052.com/tutmemor.phtml